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Sustainable Diet Bundles: A New Business Model Based on ESG Viewpoints

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ABSTRACT

A new business model which intended to promote public health by providing daily optimized sustainable diet bundles from retailers to consumers was proposed. The model was initiated from ESG perspectives. Specifically, the optimized diet bundle includes environmental, social, and governance considerations. To maintain a sustainable environment and be friendly to earth, the diet bundle is aimed to include the lowest carbon footprint. As for the social perspective, people must absorb enough calories, have balanced nutrients, and are affordable. And from the perspective of governance, the retail company must make adequate profits. When the number of candidate items becomes large, the problem mentioned above concerns with complex combinatorial optimization. To solve this kind of problem, we constructed a mathematical model and then employ Binary Integer Programming to find solutions according to personal needs. Experimental results show that the proposed model can quickly generate daily diet bundles which are friendly to environment with the lowest carbon footprint, are healthy, nutrition-balanced, and affordable for consumers, and can make suitable profits for the retail companies.

Keywords: Diet Bundle, ESG, Carbon footprint, Calories, Nutrients, Integer Programming, Combinatorial Optimization

INTRODUCTION

To stay ahead of competitors, a retail company frequently needs to develop a new business model to offer better services to consumers. A business model is a strategy or approach a company uses to generate revenue and ensure its long-term sustainability [1]. In developing a business model, companies must consider competition in the business environment as well as the changes in the natural environment. It is critical for all companies to employ a suitable approach to reduce possible negative influences caused by future environmental change and yet to be profitable. In this paper, we proposed to use ESG viewpoints [2-3] to help retail companies to develop a new business model, which aimed to provide sustainable diet bundles to consumers for everyday life. ESG stands for **E**nvironmental, **S**ocial, and **G**overnance. Under this broad umbrella, a retail company may develop daily diet bundles for consumers in a sustainable way: environmental (low-carboned), social (healthy, balanced, and affordable), and governance (profitable and overall).

Firstly, from the **E**nvironmental perspective, the diet bundle should include food and drink in such a way that the total greenhouse gas (GHG) emissions generated is as low as possible. The total greenhouse gas emissions, which are caused by an individual, event, organization, service, or product, are recorded and analyzed by “carbon footprint” and are generally expressed as carbon dioxide equivalent (CO_2e) [4-5]. The carbon footprint of food [6] refers to the greenhouse gas emissions generated throughout its entire life cycle, which includes growing, nurturing, farming, processing, storing, shipping, disposing, and so on. If one wants to be friendly to the environment, the simplest way is to select a friendly diet which minimizes the total carbon footprint.

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As for the **S**ocial perspective, the diet bundle should make a person healthy. To let the body work normally, each person must absorb enough calories and the diet should be balanced, which means to cover all kinds of nutrients that the body needs. The number of calories a person needs depends on their weight. For a healthy, balanced diet, men usually require around 2,500 kcal per day to maintain their weight, while women typically need about 2,000 kcal. [7]. In addition to the weight, an ideal daily intake of calories varies with age and levels of physical activity [8]. To maintain a healthy weight, it is important to balance the calories consumed from food and drink with the calories burned through physical activity. In addition to calories, the daily diet bundle should be affordable for consumers, depending on their incomes. A person with a higher income can have a higher budget to compose their daily diet, while the others have a lower income will be more likely to pay less. Furthermore, the diet had better include all categories of food and drink to keep balanced. "Five a day" is suggested by many healthy organizations. A diet that includes different colorful fruits and vegetables helps people stay healthy and can help reduce their risk for many chronic diseases [9].

Finally, from the **G**overnance perspective, a good business model should help companies ensure that they have reasonable profits to pursue sustainable development. The profit of an item is equal to the sale price minus the cost of the item. The total profit of the diet should be greater than a pre-assigned value that the company plans. In addition to the profit, the retail company can present a mechanism which compromises the conflicts between the **E**nvironmental and **S**ocial influences.

Though we know the general guideline, a real problem we must seriously face every day is determining what food and drink we should take. Consequently, there is a need to develop an effective system that can generate a daily diet bundle according to personal requirements. In the past, several studies [10-18] are related to this topic. However, none have simultaneously included environmental, social, and governance aspects. To be friendly to the environment, consumers might need to pay more money and the company might have to shrink profits. Tradeoff between the generation of carbon footprints, the consumers' budgets, and the company's profit forms a very complicated decision problem. Finding an optimal object from a finite set of objects and satisfying the objective and constraints belongs to the combinatorial optimization problem [19-21]. When there are many kinds of food candidates and constraints, the combinatorial optimization problem becomes quite complex and even leads to combinatorial explosion [22]-[24]. Given this understanding, it is not possible for us to compose a sustainable diet bundle without an efficient tool. We need to use an appropriate tool to help consumers to generate feasible solutions efficiently.

To assist consumers in selecting appropriate food and drink, in this paper we develop an optimization model aiming at generating a suitable diet bundle that minimizes carbon footprint, meets required calorie intake, offers an affordable price for consumers, and ensures reasonable profits for the company. Binary Integer Programming is used to solve this optimization problem, helping retailers provide optimized diet bundles. To explore the impact of different parameters, various experiments were conducted across multiple scenarios.

The remainder of this paper is organized as follows. The problem is introduced elaborately and the mathematical formulation is presented in Section 2. The solution-finding scheme is explained in Section 3. Experimental results and some discussions are addressed in Section 4. Finally, conclusions and some suggestions about future studies are presented in Section 5.

THE PROBLEM

Based on personal data such as age, gender, weight, and activity level, the task is to assist consumers in finding an optimized diet bundle. This bundle consists of various food and drink options from a predefined set of items, with the goal of minimizing the total carbon footprint of the selected items. Additionally, several constraints must be met. To simplify the explanation, we begin by defining key variables first as follows. Let i = 1, 2, …, m represent the category of candidate items, where m is the total number of categories. For each category i, there are n_i different candidate items, depending on the category. The carbon footprint, calorie, sale price, and expected profit of j^{th} item in category i are represented by c_{ij}, k_{ij}, b_{ij}, and p_{ij}, respectively.

Objective function:

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From the Environmental perspective, the objective function Z is to minimize the sum of carbon footprints (CO_2e amounts) of all the selected items.

$$\text{Minimize} \quad Z = \sum_{i=1}^{m} \sum_{j=1}^{n_i} c_{ij} x_{ij} \tag{1}$$

Constraints:

From the **S**ocial perspective, the diet bundle should be healthy, balanced, and affordable. To keep healthy, the first constraint is to obtain a suitable amount of calories. Given some personal information like age, gender, weight, and activity level, the required calories K_{req} for a consumer every day can be expressed as

$$\sum_{i=1}^{m} \sum_{j=1}^{n_i} k_{ij} x_{ij} \leq K_{req} - D \tag{2}$$

where D is the allowed difference of calories between the actual and the required calories and $D \geq 0$. When D approaches zero, the sum of the calories of all the selected items is close to the required calories. In addition, the diet bundle must include at least one item in each category to keep balanced. The number of items in each category can be set up in advance, as expressed in Eq. (3), where $(A_L)_i$ and $(A_U)_i$ are the lower and upper bounds of selected items in category i and $(A_L)_i \geq 1$, ensuring that the diet bundle can include every category [18].

$$(A_L)_i \leq \sum_{j=1}^{n_i} x_{ij} \leq (A_U)_i \qquad i = 1, 2, \ldots, m \tag{3}$$

Moreover, “five a day’ is expected. The total number of fruit and vegetable is set to be V_{tot}, where in general $V_{tot} = 5$ [18].

$$\sum_{i=1}^{m} \sum_{j=1}^{n_i} x_{ij} \geq V_{tot} \qquad i = 1, 2, \ldots, m; j = 1, 2, \ldots, n_i \tag{4}$$

Furthermore, the total sale price of the diet bundle is not greater than the budget of a consumer, i.e., the consumer is affordable.

$$\sum_{i=1}^{m} \sum_{j=1}^{n_i} b_{ij} x_{ij} \leq B \tag{5}$$

where B is the budget of the consumer.

From the perspective of **G**overnance, the retail company should be profitable.

$$\sum_{i=1}^{m} \sum_{j=1}^{n_i} p_{ij} x_{ij} \geq P \tag{6}$$

where P is the expected profit that a company sets.

Other constraints include:

(i) The total number of the selected items is bounded, as expressed in Eq. (7).

$$N_L \leq \sum_{i=1}^{m}\sum_{j=1}^{n_i} x_{ij} \leq N_U \qquad i = 1, 2, \ldots, m; j = 1, 2, \ldots, n_i \tag{7}$$

where N_L and N_U are the lower and upper bounds of the total number of the selected items [18].

(ii) Variable constraint

$$x_{ij} \in \{0, 1\} \qquad i = 1, 2, \ldots, m; j = 1, 2, \ldots, n_i \tag{8}$$

where

$$x_{ij} = \begin{cases} 1 & \text{if item } j \text{ in category } i \text{ is selected,} \\ 0 & \text{Otherwise} \end{cases}$$

If a candidate item is unacceptable by a consumer, x_{ij} can be set as 0. For example, if a consumer is vegetarian, the value of the items belonging to meat can be set to be 0. Equation (1) is the objective function, which is to minimize the sum of carbon footprint of all the selected items. Furthermore, the sum of calories is not greater than the required amount of calories K_{req} for a consumer, as depicted in Eq. (2), where $D \geq 0$. Equation (7) requires the total number of the selected items to be between N_L and N_U. The decision variable is x_{ij}, being either 0 or 1, as shown in Eq. (8). If the i^{th} category and its j^{th} item is selected, $x_{ij} = 1$.

Method of Solution

To obtain feasible and useful solutions, the solution-finding scheme is referred [18] and a modified one is proposed . The scheme is composed of three phases, as shown in Fig. 1.

In the phase I, the required data are collected and/or calculated. To calculate the required calories for a consumer, the necessary data including gender, weight, age, and physical activity level should be known. The calories data of the candidate items can be found from some literature, mainly based on References [25-26] in this paper. The prices and profits are collected from some retailers. As for the carbon footprint, a lot of data are collected directly from a few databases or literature [27-30], while some other data are evaluated by several calculators [31-33]. The carbon footprint data for many foods or drinks are still not available, causing the data for experiments are limited.

In the phase II, we employ Binary Integer Programming to solve the problem. Both Python and Excel are used to find solutions. The main steps to find solutions include:

(1) The setting of the objective function: The objective is to minimize the total carbon footprints (CO_2e amounts), which are collected and aggregated from each selected item.

(2) The setting of the decision variables: The decision variables are integer and binary, i.e., being zero or one.

(3) The setting of the constraints: There are many constraints, which includes the calorie constraint, “five a day” constraint, budget constraint for the consumer, and profit constraint for the company, and so on.

(4) Coding of the program

(5) Input of the required data and data validation

(6) Program validation

(7) Execution of the program and generation of the solutions

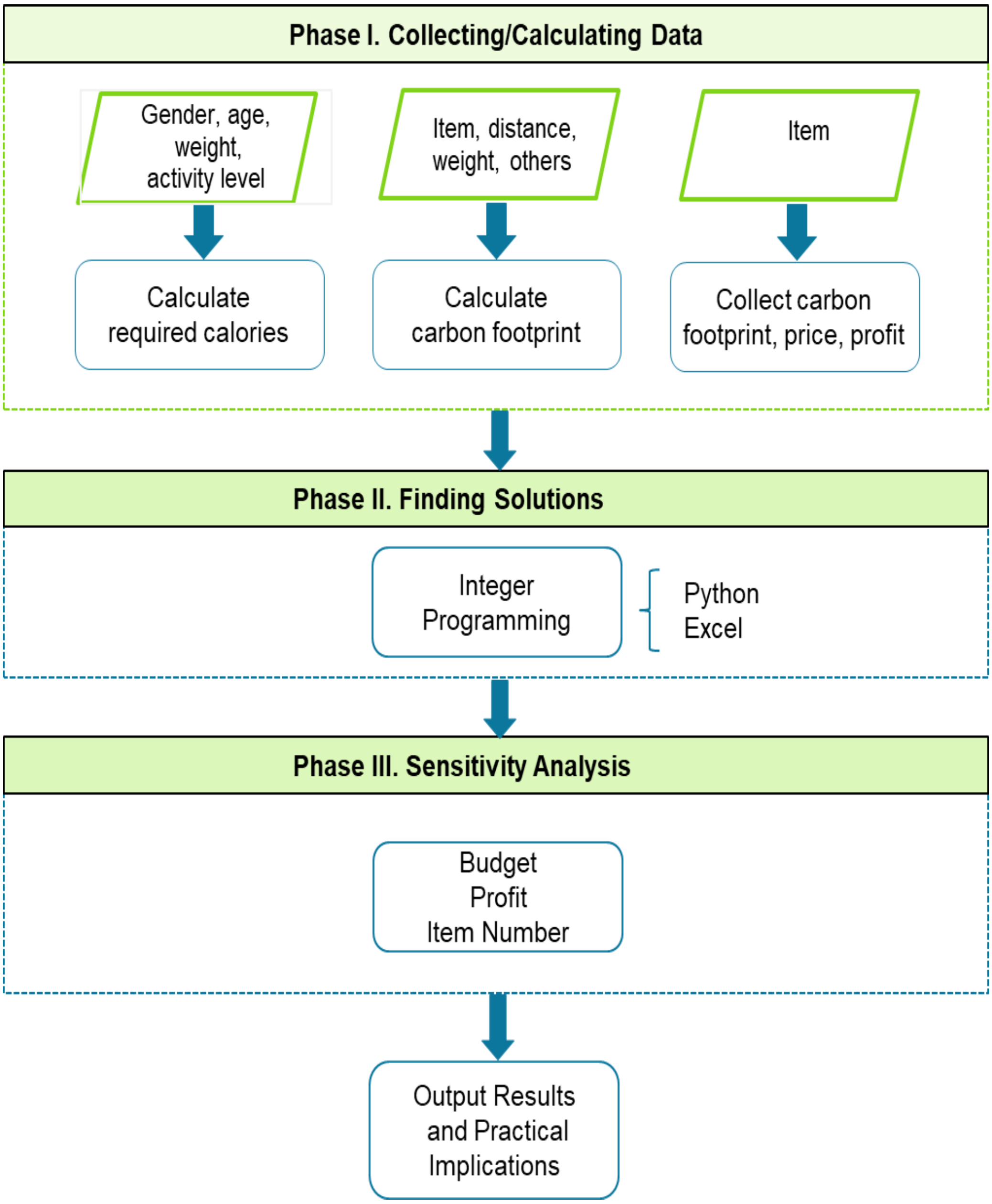

Fig. 1. The solution-finding scheme.

In the phase III, sensitivity analysis is performed and a lot of experiments are executed. The influences of the consumer's budget, the company's profit, the total number of items on the results are investigated.

RESULTS AND DISCUSSION

To investigate the effectiveness of the proposed approach, a base case was set up. Referring to Chen et al. [18], food and drink can be divided into seven categories at the base case: (1) grains, (2) meats & protein, (3) soy & milk, (4) vegetables, (5) fruits, (6) dessert, bread and snack, (7) beverages. The total number of candidate items is 150 at the base case. Each category includes different number of items ranging from 14 to 35, as shown in Table 1. The lower and upper bounds of the number of selected items A_L and A_U in each category are also set in advance. The required calories are pre-assigned as 2,200 kcal, which is based on a 31-50 years old male people with low level of physical activity. The allowed difference D between the actual and required calories is 2 kcal. Furthermore, the budget B of an average consumer at the base case is 300 NTD. The expected profit P is 50 NTD for the retail company, which is equal to 1/6 of consumer's budget B. The lower bound N_L and the upper bound N_U of the total selected item number are 10 and 15, respectively. Special note must be taken that some additional constraints can be added to generate more

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personalized results.

Table 1. Each category and its number of items at the base case.

	Category	**Number of items, n_i**	A_L	A_U
1	Grains	24	1	3
2	Meats & protein	21	1	3
3	Soy & milk	14	1	3
4	Vegetables	19	2	5
5	Fruits	20	2	5
6	Dessert, bread, & snack	17	1	2
7	Beverages	35	1	2

The problem is solved using Binary Integer Programming. A typical solution is shown in Fig. 2. Note that at the base case N_L = 10 and N_U = 15 and the total number of the selected items at the optimal solution is 13. Apparently, the solutions depend on the values of N_L and N_U. To obtain a suitable diet bundle according to consumer's preference, it is important to set appropriate lower and upper bounds of the total number of the selected items.

```
Total Calories: 2199
Total CO2: 0.622
Total Price: 300
Total Profit: 50
Diet Bundle List:
+----------------+---------+--------+------------+-----------+
| Name           | Unit    | Weight |  Calories  |    CO2    |
+----------------+---------+--------+------------+-----------+
| Rice           | Bowl    |  205   |   225.0    |  0.0213   |
| Wheat          | Serving |  100   |   362.0    |  0.075    |
| Roasted Peanut | Serving |   50   |   300.0    |  0.07     |
| Shellfish      | Serving |  100   |    77.0    |  0.0361   |
| Butter         | Serving |  100   |   679.0    |  0.11     |
| Carrot         | Serving |  100   |    41.0    |  0.01     |
| Starfruit      | Serving |  100   |    34.0    |  0.0739   |
| Apple          | Serving |  100   |    45.0    |  0.02     |
| Fig            | Serving |  100   |    74.9    |  0.02     |
| Guava          | Serving |  100   |    39.0    |  0.01     |
| Pomegranate    | Serving |  100   |    67.0    |  0.02     |
| Potato chips   | Serving |  100   |    39.0    |  0.01     |
| Green Tea      | Pack    |  250   |    84.0    |  0.11     |
+----------------+---------+--------+------------+-----------+
```

Fig. 2. A typical solution with 13 items.

It is very easy to find a more personalized solution. For example, if a consumer is vegetarian, the items belonging to meat can be set to be 0 and they will be rejected from the diet bundle. On the contrary, if the consumer likes a particular item, just set the lower and upper bound to be one and then the diet bundle will include this item.

The influence of budget

To evaluate the influences of different consumers' budgets *B* on the results, the values of *B* are varied from 50 to 600, with an increment of 50 NTD. Similar as at the base case, we set $N_L = 10$ and $N_U = 15$ in the following experiments. The experimental results are summarized in Table 2. If the budget is too small, no feasible solutions can be found. To obtain feasible solutions, a reasonable budget should be given. As the budget increases, the minimum carbon footprint (expressed with CO_2e amounts hereafter) is lowered, which is favorable to environment. To be friendly to the environment, the consumer needs to increase the daily diet budget. Therefore, there should be a tradeoff between the environment and affordability. On the other hand, the marginal influence on the CO_2e amount decreases with budget when the budget is large. When the budget exceeds 500 NTD, the solution remains the same.

Table 2. The influence of different budgets *B* on the results.

Budget *B* (NTD)	**CO_2e (kg)**	**Calorie (kcal)**	**Profit (NTD)**	**Total price (NTD)**
50	infeasible			
100	infeasible			
150	1.187	2,198	52	149
200	0.945	2,198	50	198
250	0.810	2,200	50	248
300	0.622	2,199	50	300
350	0.533	2,200	53	348
400	0.459	2,200	50	399
450	0.388	2,200	52	444
500	0.369	2,199	56	473
550	0.369	2,199	56	473
600	0.369	2,199	56	473

The influence of expected profit

For companies, the most important issue is to make profits. The influences of the expected profits on the result are also investigated in this paper. The expected profits are increased from zero with an increment of 10 NTD up to 80 NTD. As the expected profit of the company increases, the CO_2e amounts also increase. Figure 3 shows this trend. For small expected profits, the increase in CO_2e amount is insensitive to the expected profit. However, a significant increase in CO_2e amounts appears when the expected profit exceeds 50 NTD. There is a trade-off between making more money and doing go to the environment. To benefit environment, the company needs to sacrifice some profits. Experiments also show that it is more difficult to find solutions when the expected profits become larger.

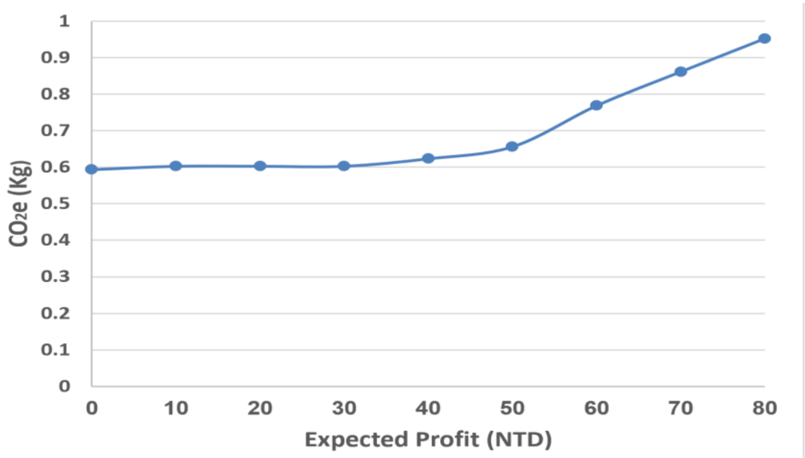

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Fig. 3. The influences of different expected profits on the carbon footprint.

Figure 4 shows the influences of budgets with different profits on the carbon footprint. With a same consumer's budget, a lower CO_2e amount can be obtained with a lower company's profit. In addition, with a fixed CO_2e amount, a higher consumer's budget leads to a higher company's profit.

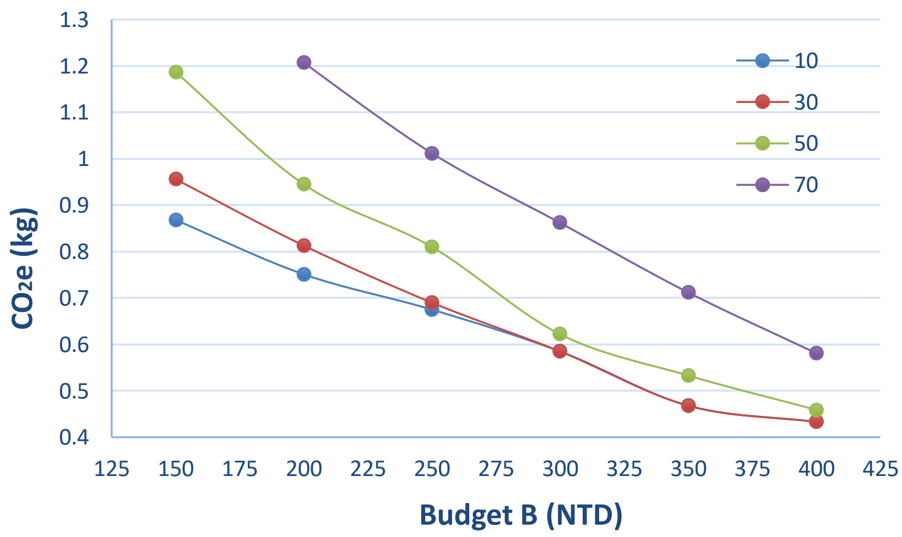

Fig. 4. The influences of budgets with different profits on the carbon footprint.

The influence of total selected item number

To evaluate the influences of the total selected item number on the results, different lower and upper bounds of item number are set. In the experiments, the required calories are preassigned as 2,200 kcal, the value of D is 2 kcal, the budget is 300 NTD, the expected profit is 50 NTD, and the values of N_L and N_U are both changed from 10 to 20. To ensure that a balanced and healthy diet bundle can be generated, at least one item is selected for each category and the number of fruits plus vegetables is not less than five, as previously depicted in Table 1. The experimental results are shown in Table 3.

Table 3. The influence of total selected item number on the results.

N_L	N_U	CO_2e (kg)	Calories (kcal)	Profit (NTD)	Total Price (NTD)
10	10	0.732	2,199	51	287
11	11	0.664	2,199	50	299

12	12	0.622	2,199	50	300
13	13	0.656	2,199	50	295
14	14	0.693	2,199	50	297
15	15	0.756	2,200	52	300
16	16	0.838	2,198	55	297
17	17	0.903	2,200	50	299
18	18	0.973	2,199	51	296
19	19	1.027	2,199	50	293
20	20	1.149	2,198	50	297
10	20	0.622	2,199	50	300
11	20	0.622	2,199	50	300
12	20	0.622	2,199	50	300
13	20	0.656	2,199	50	295
14	20	0.693	2,199	50	297
15	20	0.756	2,200	52	300
16	20	0.838	2,198	55	297
17	20	0.903	2,200	50	299
18	20	0.973	2199	51	296
19	20	1.027	2199	50	293

As the values of N_L and □ increase, the CO_2e amount decreases down to a minimum value and then increases again, as shown in Fig. 5. This is an important finding that a suitable item number should be given in order to obtain a lowest amount of CO_2e.

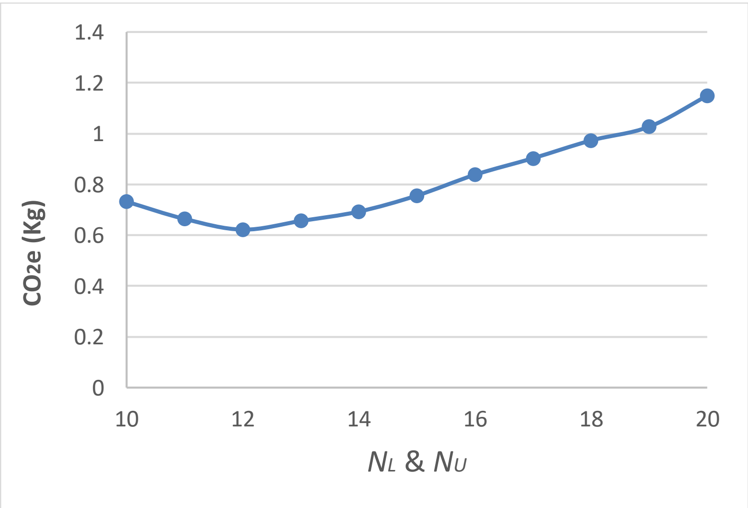

Fig. 5. The influences of different total selected item number on the carbon footprint.

CONCLUSIONS AND RECOMMENDATIONS

In this paper, a new business model planning optimized sustainable diet bundles to consumers has been proposed. Based on an ESG (**E**nvironmental, **S**ocial, and **G**overnance) approach, the business model is presented. From the **E**nvironmental perspective, the diet bundles should generate CO_2e as low as possible, resulting in less negative influence on environment. As for **S**ocial perspective, people must absorb enough calories, have balanced nutrients, and are affordable to buy the diet bundle. And from the perspective of **G**overnance, the company must generate enough profits via the new business model. As the number of candidate items of the diet bundle and the constraints become large, the planning of diet lists becomes a very complex problem. To tackle the problem, we first set up an optimization model and then employ Binary Integer Programming to obtain feasible solutions which are according to personal needs. Results show that the proposed business model can efficiently generate diet bundles which are friendly to environment, are healthy, nutrition-balanced, and affordable for consumers, and can make reasonable profits for the retail companies. In addition, when the budget of a consumer increases, the carbon footprint decreases, influencing the environment positively; when an expected profit for a company gets larger, the carbon footprint also increases, negatively influencing the environment. Therefore, a tradeoff should be made between the consumer's budget, the company's profit and the carbon footprint.

Though experiments performed in this study are based on real data and some literature, more actual data on carbon footprints are greatly needed. In the future, studies may focus on collecting more carbon footprint data and their applications. This paper presents a good approach for daily diet bundles. Further studies can aim to generate a weekly-based diet bundles. Moreover, a family-based diet bundles which consider several peoples' needs can be investigated. Another interesting research topic is to use some heuristic algorithms to explore more useful and feasible solutions to provide more alternatives for consumers.

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APPENDIX: NOMENCLATURE

Subscripts:
i: i^{th} category of item
j: j^{th} item
L: lower bound
req: required
tot: total
U: upper bound
A_L: lower bound of item number, Eq. (3)
A_U: upper bound of item number, Eq. (3)
b_{ij}: the sale price of item *j* in category *i*
B: the budget of a consumer
c_{ij}: the CO_2e amount of item *j* in category *i*
D: the allowed difference of calories from the target
k_{ij}: the calories of item *j* in category *i*
K_{req}: the required calories for a specific consumer
m: the total number of categories of items
N_L: the lower bound of the total number of the selected items
n_i: the total number of items in category *i*
N_U: the upper bound of the total number of the selected items
p_{ij}: the profit of item *j* in category *i*
P: the expected profit of a company
V_{tot}: the total number of fruits and vegetables
Z: the objective function