Nutrition Intake Control for Out-eaters in Taiwan with Adaptive Dietary Management Model

Jung-Bin Li* & Wei-Jan Huang**

*Department of Statistics and Information Science, Fu-Jen Catholic University, New Taipei City, TAIWAN R.O.C.
E-Mail: 071635{at}mail{dot}fju{dot}edu{dot}tw
**Department of Statistics and Information Science, Fu-Jen Catholic University, New Taipei City, TAIWAN R.O.C.
E-Mail: wei.jan1277{at}gmail{dot}com

***Abstract*—**This study adopts a decision support model to provide regular out-eaters healthy and appropriate dietary menus based on their individual needs and preferences. By taking advantage of analytic hierarchy process and multi objective programming, the adaptive dietary management model gives dietary recommendations to meet all constraints and object functions which are customized according to each user's body mass index, intensity of work, and other criteria. The outcomes of model recommendation reveal a dilemma for regular out-eaters in Taiwan that limited dining budget tends to have food combinations with insufficient intake in categories vegetable and dairy. Kiosks or booths along the street offer food with much lower prices, but they are out of consideration of the experts consulted in this study. Another noteworthy fact is that most foods collected in this study have excessive sodium and energy. This problem enhances the difficulty to organize a satisfactory dietary combination.

***Keywords*—**Analytic Hierarchy Process; Dietary Control; Health Management; Multi-Object Programming.

***Abbreviations*—**Analytic Hierarchy Process (AHP); Multi-Object Programming (MOP).

I. INTRODUCTION

TAIWAN has been well-recognized as a place filled with cuisines and snacks [1]. Both local residents and tourists find choices which meet their need easily. However, such convenience brought by the booths and vendors caused people unwilling to cook by themselves. A local report reveals that there are over 2.7 million adults buy their dinners instead of self-catering on a daily basis [2]. The same study indicates over 50 percent of local citizens have a shortage in taking vegetables and fruits.

To address this issue, the importance of dietary equilibrium has been urged by the public sector. In 2014, the Ministry of Health and Welfare of Taiwan released press publications to remind regular out-eaters about the common problems of dining out: excessive calories, too much intake on grease and salt, and insufficient dietary fibers. Since these problems have negative effects on health, it becomes critical for people to keep track on daily nutrient intakes while fitting other considerations such as variety and budget. This study therefore proposes a decision support model to resolve multiple evaluation criteria for out-eaters. The motivation of this study is to:

a. provide convenient dietary planning among popular chain stores/restaurants.
b. find proper combination of food, based on personal need, to fill his/her DRI.
c. have a customized way of dietary management rather than solely based on expertise.

II. LITERATURE REVIEW

2.1. *Healthy Dietary*

The issue of healthy dietary has drawn much attention worldwide. In recent years, many researches has concluded that keeping appropriate nutrient intake and variety of food and drinks may benefit cardiac health and reduce the risk of having cardiovascular diseases and cancer [3-6].

Although ordinary people have better understanding of healthy dietary, it is still a common problem to satisfy nutrient intake in every single criteria. The Food and Nutrition Board of the Institute of Medicine (IOM) works in cooperation with Canadian scientists and proposes a comprehensive reference of nutrient intakes to U.S. and Canadian citizens. In this report, the Recommended Dietary Allowances (RDAs) establishes a set of reference values for dietary energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids. Close attention was given throughout the report to the evidence relating macronutrient intakes to risk reduction of chronic disease and to amounts needed to maintain health [7].

Because this study takes Taiwanese residents as the research target, all the recommended amounts of intakes or indices refers to the data published by Food and Drug Administration, Ministry of Health and Welfare, Taiwan in 2011. According to the Dietary Reference Intakes (DRI) of domestic residents, the suggested amount of intake of protein, dietary energy, 13 vitamins and seven minerals differs in terms of age and sex. Therefore, every person should have his or her own proprietary dietary plan to meet all nutrients. The same administration defines recommended dietary energy based on the Body Mass Index (BMI) of local citizens. With given sex, age, intensity of work, responding values of dietary energy and units of intakes in six dietary categories are suggested respectively.

2.2. A Hybrid Model of AHP and MOP

In literature, studies have shown that by linking the analytic hierarchy process (AHP) and multiple objective planning (MOP), the hybrid decision making model can be more flexible than the conventional MOP. Another approach adds both tangible and intangible restrictions into the planning model, and gives weight values to the evaluation criteria. It makes the model better customized [8-12].

Based on the above review, whether the model is more flexible, closer to reality, more customized, or if considering limitations of tangible and intangible factors, can be taken into account on the creation of perception value. According to Zeithaml [13], the perceived value given by consumers is an overall evaluation of product based on what they perceived in terms of what they pay and what they have. Therefore, the combinational models mentioned in last paragraph offer better perceived value in comparison with the MOP model.

The prior work [14] of this study proposed a hybrid model which gives dietary recommendation based on expert opinions and personal feature with the capability of personalized adaptation. This study further elaborates by giving an analysis and discussion based on simulated scenarios.

III. METHOD DESCRIPTION OF ADMAM

The architecture of the formerly proposed model ADMaM is shown in Figure 1. By adopting multiple criteria decision-making approaches AHP and MOP, this model attempts to combine expertise in nutriology and opinions from out-eaters. The proposed model has two blocks: one is AHP module, and the other one is MOP module, which have feedback mechanisms to make this model adaptive to individual preferences.

In this model, decision makers will be asked to answer questionnaire in system or to take the default weight values. The default values come from the AHP result of our pre-collected data set. If the decision maker responds to the questionnaire, this system put the answers as a new entry in the data set. By adjusting the coefficient of weight, the system may offer a planning output which is different from the one with default weight values. The second module, i.e., MOP, then organizes and recommends dietary combinations based on the result of AHP. If the decision maker does not like to be interfered by expertise, this system also supports overrule mechanism to allow his arbitrary decision.

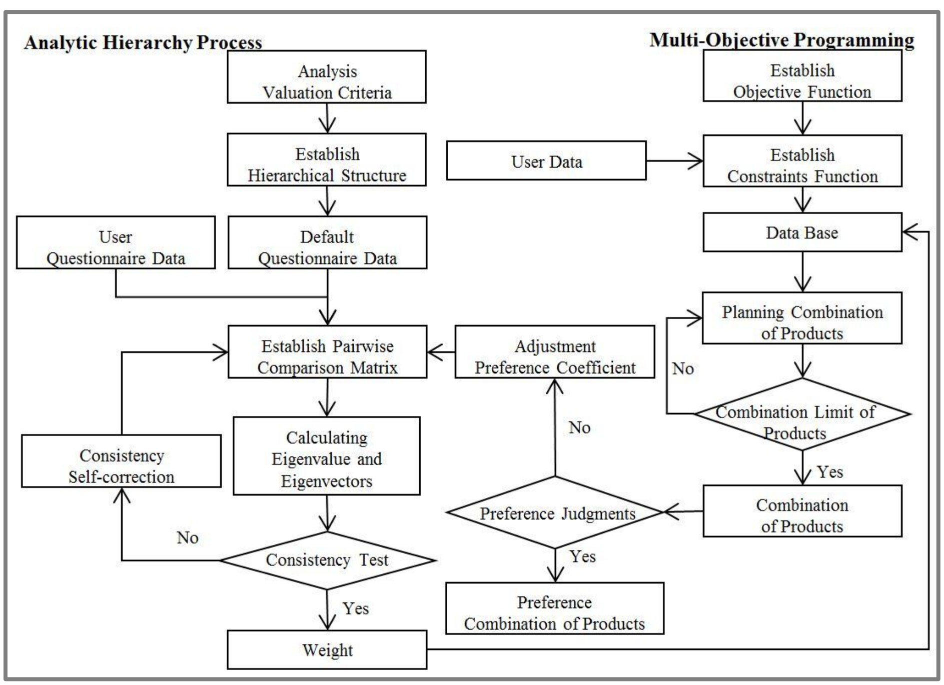


Figure 1: Architecture of the ADMaM Model [14]

3.1. Building AHP Model

This study aims at the issue of dietary health and proposes an adaptive model in which AHP and MOP are linked with feedback mechanism. By taking both nutriology experts and ordinary out-eaters into consideration, along with the decision maker's individual attributes (i.e., age, sex, and etc.), this hybrid model gives healthy dietary planning recommendations.

Due to the limitation of work and living locations, dietary habits are different from person to person. This situation usually leads to the problem of not being able to have sufficient and balanced intake in every category of nutrients. Besides, out-eaters have different level of acceptance regarding to the price and quality of product. According to these issues, six evaluation criteria are considered influential when decision makers choose their dietary combination: convenience, product diversity, nutritional balance, price, consistency of quality, and brand acceptance.

In this study, we chose four chain stores or restaurants as the evaluation targets: fast food chains (e.g. McDonald's), convenience stores (e.g. 7-11), Taiwanese restaurants (e.g. 8way), and complex restaurants (e.g. Starbucks). A layered architecture is built in the following manner.

- First layer: final objective – priority of restaurants or stores.
- Second layer: evaluation criteria – convenience, product diversity, nutritional balance, price, consistency of quality, and brand acceptance.
- Third layer: evaluation factors – fast food store, convenient store, Taiwanese restaurant, and complex restaurant.

The study builds model data set from 30 respondents in metropolitan Taipei, including 15 professionals with expertise in nutriology or food science, and the remaining 15 regular out-eaters without professional knowledge in different age levels. Based on the collected data entries, pairwise comparison matrices are calculated to evaluate each pair of factors. The Consistency Index (C.I.) and Consistency Ratio (C.R.) are examined to validate if the matrices are consistent. When $C.I. \le 0.1$ and $R.I. \le 0.1$, the degree of consistence is acceptable. Table 1 shows that the result of validation is satisfactory.

Table 1: Pairwise Comparison Matrix of the Evaluation Criteria in the Second Layer of AHP

	Convenience	Product Diversity	Nutritional Balance	Price	Consistency of Quality	Brand Acceptance
Convenience	1	2.11	1	0.88	0.80	1
Product Diversity	0.50	1	0.50	0.62	0.67	0.75
Nutritional Balance	1	2	1	1.29	1.14	1.60
Price	1.14	1.62	0.78	1	1.43	1.43
Consistency of Quality	1.25	1.50	0.88	0.67	1	1.43
Brand Acceptance	1	1.33	0.62	0.71	0.75	1
C.I.=0.0602				C.R.=0.0485		

The weight value of each criterion is calculated after validating the matrix consistency. As shown in Table 2, convenience store (CVS) has the highest value (0.381) over the other three choices. These weight values will be the basis for our data analysis in the next step.

Table 2: Weight values of AHP

	Convenience	Product Diversity	Nutritional Balance	Price	Consistency of Quality	Brand Acceptance	Overall
Fast Food Restaurant	0.335	0.143	0.128	0.077	0.543	0.370	0.259
CVS	0.454	0.440	0.203	0.674	0.250	0.302	0.381
TaiwaneseFood	0.144	0.194	0.433	0.186	0.093	0.125	0.215
Complex Restaurant	0.068	0.223	0.237	0.063	0.114	0.203	0.146

3.2. Building MOP Model

This study refers to the suggested nutrient intakes from Food and Drug Administration, Ministry of Health and Welfare of domestic government. The dietary energy and nutrients needed for keeping people healthy are comprised by carbohydrate, protein, fat, dietary fiber and minerals. In this study, dietary energy and three major nutrients including carbohydrate, protein, and fat are taken as the pursuing objectives. Dietary recommendation of the proposed model suggests products with nutrient management closer to the optimal vales. This model considers budget as another objective which needs to be organized.

3.2.1. Objectives

O1: Intake optimization in each food category

The nutrients needed by human body come from various foods in the six categories defined by the public sector mentioned earlier. Although the foods in different categories cannot be replaced by each other, products offered by chain restaurants and stores are limited in reality due to commercial policies. This objective intends to find product combinations which best satisfies the suggested daily intakes in six categories of food. If the suggested intake cannot be satisfied, a closest combo will be the compromised solution. This objective is formulated as in (1).

$$MaxZ_1 = \sum_{i=1}^{6} \sum_{j=1}^{n} (CN_{ij} - KN_i) \quad (1)$$

O2: Intake optimization of dietary energy

Dietary energy is what people need everyday for muscular movements and organic activities. Either excessive or insufficient intake may have negative influence on body health. This study intends to recommend dietary combinations with closest energy level but not over the suggested value. The dietary energy is calculated based on people's individual body mass index (BMI) and his/her intensity of work. This objective is formulated as in (2).

$$MaxZ_2 = \sum_{i=1}^{n} Cal_i \quad (2)$$

O3: Budget optimization

Based on model user's personal needs, this study intends to provide product combinations which best utilize the given budget. This objective is formulated as in (3).

$$MaxZ_3 = \sum_{i=1}^{n} CM_i \quad (3)$$

O4: Dietary preference optimization

The study intends to provide suggestions which best fit user's individual preferences. This model hence has a feedback mechanism to adjust preference coefficient as system parameter.

3.2.2. Constraints

C1: Budget

The total amount of money for recommended product combination cannot be higher than user budget. This constraint is formulated as in (4).

$$\sum_{i=1}^{n} CM_i \leq M \quad (4)$$

C2: Time slot for dining

Because some chain restaurants and stores have different menus or products for different time slots, this study regards such situation as a constraint.

C3: Minerals

Although minerals are necessities of human body, excessive intake may cause negative effects. For example, the suggested daily intake of sodium in Taiwan is 2400 mgs, roughly 6 grams of salt, which is generally the same as World Health Organization (WHO) suggested. However, the actual daily intake of sodium for Taiwanese adult is up to 9~10 grams. Excessive intake of sodium may cause hypertension, atherosclerosis, or cardiac diseases. This study sets mineral intake as a constraint to meet suggested value but not over the upper limit, as formulated in (5).

$$\sum_{i=1}^{n} CNa_i \leq KNa \quad (5)$$

C4: Dietary energy allocation on each meal of a day

The suggested daily dietary energy intake is different depending on one's height, weight, age, sex, and his/her intensity of work. This study follows the principle recommended by the public sector and allocates energy intakes by meal as 30%, 40%, and 30% of daily quota for breakfast, lunch, and dinner respectively.

C5: Caffeine

Adequate caffeine helps people to stimulate central neural system and to relieve fatigue. But excessive intake of caffeine may have negative effects including Parkinson's disease, heart disease, and certain types of cancer. This study hence considers caffeine intake as a constraint in model, formulated in (6).

$$\sum_{i=1}^{n} CCaf_i \leq KCaf \quad (6)$$

C6: Non-negative value

All foods contain a variety of nutrients, and their amounts of content are naturally positive. It is considered a fault if the content is marked as negative.

IV. STUDY IN SIMULATED SCENARIOS

4.1. Scenario Settings

The purpose of this study is to find dietary planning solutions for regular out-eaters in metropolitan Taipei. Therefore a simulation scenario is set up for observing model outputs and further analysis. The simulated decision maker is a 25-year-old male, light working intensity, whose height is 1.83 meters and his weight is 73 kilograms. This proposed model can be operated either by taking default system weight values or by answering personal preferences in evaluation criteria. The default values are computed from the original data set of this study. If decision maker chooses to answer questionnaire, his/her preferences will be computed altogether with other data entries in our data set, with given his subjective weighing coefficient. When the preferred restaurant/store is decided by AHP module, planning the dietary combination is the next step of our MOP module. Candidate food and drink products in this study make 2096 entries of our database.

To give further discussions and analyses, this study sets up five simulated scenarios and takes them as the model input. These scenarios are listed in Table 3.

Table 3: Scenario Settings

Scenario No.	Height (M)	Weight (Kg)	Age	Sex	Working intensity
S1	1.83	73	25	Male	light
S2	1.63	80	25	Male	light
S3	1.53	60	26	Female	light
S4	1.70	60	25	Female	light
S5	1.63	73	25	Female	high

The system flowchart of ADMaM is shown in Figure 2. When ADMaM gives recommendations, one of the two modes can be selected: applying the system default values or giving personal preference by filling a questionnaire. The system default values are the weight values obtained from the AHP module. If personal preference is given, the user's data is combined with other entries in the user database.

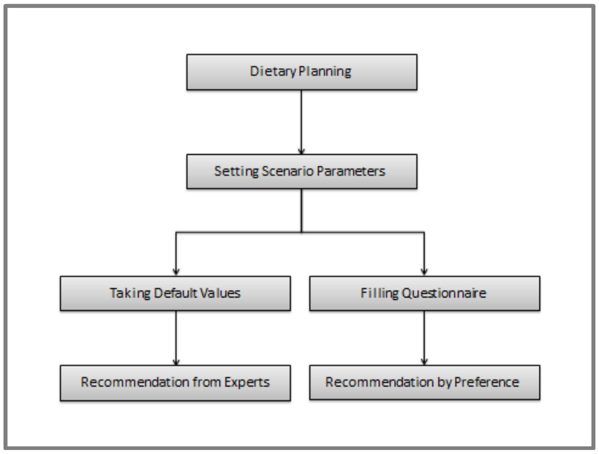


Figure 2: Flowchart of ADMaM

4.2. Planning Outcomes with Default Settings

For scenario S1, if the system default settings are taken, and the required dietary combination contains a main course, salad, and fruit, the recommended combinations with budgets 100 New Taiwan Dollars (NTD) (Case 1) and 150 NTD (Case 2) are listed in Table 4, respectively. Taking default settings in this model as mentioned earlier means that weights in the decision matrix take opinions of both nutrition experts and regular out-eaters into account, and their first choice of food source is convenience store. According to the output of this model, it is observed that the combination with higher budget better satisfies the suggested daily intakes. And if the shortage of daily intakes exists, the amount of shortage in six categories of food caused by higher budget is less than the amount caused by lower budget. A noteworthy situation has to be addressed that the shortage of nutrient intake is a common problem if only products provided by the chain restaurants and stores can be chosen in our dietary combination. With the constraint of limited budget, it is very likely to fail in finding satisfactory solutions.

Table 5 shows the nutrition obtained from the given food combination by each meal of scenario S1. According to this result, combination for Case 1 has insufficient intake in categories protein, dairy, and vegetable. If budget roof is raised to 150NTD (i.e., Case 2), intake of protein reaches the suggested value. Shortage in dairy and vegetable is also improved.

Table 4: Recommendation List by Meal of Scenario S1

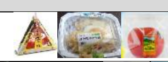
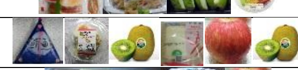
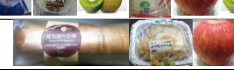
Budget	Meal	Combination	Price
100	**Breakfast**		97
	Lunch		92
	Dinner		99
150	**Breakfast**		146
	Lunch		112
	Dinner		128

Table 5: Nutrition intake by meal of scenario S1

Budget	Meal	Dietary Energy	Sodium	Caffeine	Grain	Protein	Dairy	Vegetable	Fruit	Fat
100	**Breakfast**	-4.00	-106.10	-131.40	2.90	-0.90	-0.25	-0.80	0.50	3.20
	Lunch	-48.00	-42.05	-175.20	4.70	-1.20	-0.60	-1.00	0.20	2.00
	Dinner	-140.70	-185.57	-131.40	0.90	-0.80	-0.45	0.02	0.20	1.40
	Total	-192.70	-333.72	-438.00	8.50	-2.90	-1.30	-1.79	0.90	6.60
150	**Breakfast**	-83.90	-264.36	-131.40	2.50	-0.60	-0.45	0.00	1.70	0.90
	Lunch	-14.72	-16.94	-175.20	2.40	0.50	-0.6	-0.85	1.00	1.10
	Dinner	-0.17	-63.14	-131.40	0.90	0.30	0.21	0.01	0.30	0.70
	Total	-98.79	-344.45	-438.00	5.80	0.20	-0.84	-0.84	3.00	2.70

Table 6 shows the combination results recommended by ADMaM for scenarios S2, S3, S4, and S5, respectively. All the results are conducted from same settings of forementioned scenario S1. Table 7 shows the corresponding nutrition intakes of scenarios S2, S3, S4, and S5, respectively. Similar situations can be found when poor dining budget is given, it is less likely to find reasonable recommendations which meet all objectives and constraints.

Table 6: Recommendation List by Meal of Scenarios S2, S3, S4, and S5

Scenario	Budget	Meal	Combination	Price
S2	100	**Breakfast**		87
		Lunch		100
		Dinner		98
	150	**Breakfast**		136
		Lunch		148
		Dinner		89

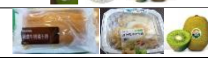
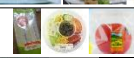
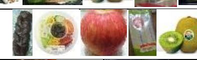
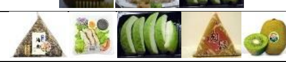
S3	100	**Breakfast**		94
		Lunch		100
		Dinner		100
	150	**Breakfast**		146
		Lunch		147
		Dinner		124
S4	100	**Breakfast**		99
		Lunch		86
		Dinner		97
	150	**Breakfast**		136
		Lunch		139
		Dinner		141
S5	100	**Breakfast**		99
		Lunch		100
		Dinner		89
	150	**Breakfast**		146
		Lunch		141
		Dinner		148

Table 7: Nutrition Intake by Meal of Scenario S2, S3, S4, and S5

Scenario	Budget	Meal	Dietary Energy	Sodium	Caffeine	Grain	Protein	Dairy	Vegetable	Fruit	Fat
S2	100	Breakfast	-61.59	-92.30	-144.00	2.90	-1.10	-0.45	-0.99	0.10	1.00
		Lunch	-275.46	-81.12	-192.00	4.10	-2.40	-0.40	-0.80	0.30	0.30
		Dinner	-180.24	-575.87	-144.00	1.70	-1.10	-0.45	-0.29	0.10	0.30
		Total	-517.29	-749.29	-480.00	8.70	-4.60	-1.30	-2.08	0.50	1.60
	150	Breakfast	-43.16	-43.67	-144.00	0.70	-0.40	0.08	-0.21	0.10	3.50
		Lunch	-20.86	-9.70	-192.00	2.40	0.30	-0.60	-1.29	1.50	0.70
		Dinner	-31.40	-44.60	-144.00	2.10	-1.20	-0.45	-1.10	0.10	0.40
		Total	-95.42	-97.97	-480.00	5.20	-1.30	-0.97	-2.60	1.70	4.60
S3	100	Breakfast	-78.25	-312.86	-108.00	1.75	-0.60	-0.45	0.00	0.40	0.40
		Lunch	-19.25	-96.00	-144.00	2.90	-0.90	-0.60	-1.00	1.20	1.50
		Dinner	-39.40	-36.19	-108.00	2.05	-0.80	-0.45	0.01	1.20	0.10
		Total	-136.90	-445.05	-360.00	6.70	-2.30	-1.50	-0.99	2.80	2.00
	150	Breakfast	-112.20	-79.65	-108.00	0.45	-0.30	0.05	-0.60	0.90	1.90
		Lunch	-85.92	-20.98	-144.00	1.10	0.00	-0.40	-0.80	1.20	0.30
		Dinner	-12.16	-388.17	-108.00	0.65	-0.20	0.08	-0.01	0.30	3.00
		Total	-210.28	-488.80	-360.00	2.20	-0.50	-0.27	-1.41	2.40	5.20
S4	100	Breakfast	-154.82	-165.36	-108.00	1.20	-1.00	0.17	0.00	0.20	-0.60
		Lunch	-257.50	-312.90	-144.00	1.70	-1.20	-0.40	-1.10	0.00	0.40
		Dinner	-207.90	-454.48	-108.00	0.50	-1.10	-0.45	0.00	0.40	0.30
		Total	-620.22	-932.74	-360.00	3.40	-3.30	-0.68	-1.10	0.60	0.10
	150	Breakfast	-30.45	-182.16	-108.00	2.40	-0.70	-0.15	0.00	1.30	0.60
		Lunch	-4.90	-382.26	-144.00	1.60	-1.40	-0.60	-0.30	1.00	0.40
		Dinner	-41.82	-325.94	-108.00	2.90	-0.70	-0.45	0.00	0.90	0.80
		Total	-154.82	-165.36	-108.00	1.20	-1.00	0.17	0.00	0.20	-0.60
S5	100	Breakfast	-402.30	-487.81	-131.40	1.70	-1.60	-0.45	-0.70	0.30	0.70
		Lunch	-79.06	-29.37	-175.20	4.70	-2.80	-0.60	-1.20	-0.10	2.30
		Dinner	-204.45	-57.65	-131.40	1.50	-1.50	-0.45	-1.40	0.30	0.40
		Total	-685.81	-574.83	-438.00	7.90	-5.90	-1.50	-3.30	0.50	3.40
	150	Breakfast	-93.30	-22.72	-131.40	4.10	-0.20	-0.25	-1.09	0.60	0.40
		Lunch	-109.06	-22.21	-175.20	3.80	1.80	-0.40	-1.00	-0.10	1.00
		Dinner	-349.32	-266.64	-131.40	1.10	-1.70	0.05	-0.70	0.60	-0.50
		Total	-551.68	-311.57	-438.00	9.00	-0.10	-0.60	-2.79	1.10	0.90

It is this study's interest to have a further test to see if only expert opinions are taken into the consideration of the AHP module in ADMaM. If the same settings (i.e., dietary combination contains a main course, salad, and fruit, with budget limit 100NTD) are applied to make recommendation based on expert opinions only, ADMaM fails to find a possible breakfast solution in scenario S1 (see Table 8).Recommendation for scenarios S2, S3, S4, and S5 are the same as S1. Meanwhile, combinations for lunch and dinner of S1both suffer from substantial shortage in all nutrition categories (see Table 9). Such situation can be attributed to the possible gap between expert's understandings of the food providers and the real case. Hence the opinions from out-eaters are necessary. They help this model better fit our objectives.

Table 8: Expert's Recommendation List by Meal of Scenario S1

Scenario No.	Mean	Combination	Price
S1	Breakfast	No result	
	Lunch		96
	Dinner		96

Table 9: Nutrition Intake by Expert's Recommendation in Scenarios S1 to S5

Scenario No.	Meal	Dietary Energy	Sodium	Caffeine	Grain	Protein	Dairy	Vegetable	Fruit	Fat
S1	Breakfast	-766.50	-720.00	-131.40	-1.20	-2.10	-0.45	-1.50	-1.20	-1.80
	Lunch	-712.00	-460.00	-175.20	0.30	-2.00	0.00	-1.10	-1.10	-1.70
	Dinner	-456.50	-220.00	-131.40	0.70	-1.30	0.15	-0.60	-0.70	-1.10
	Total	-1935.00	-1400.00	-438.00	-0.20	-5.40	-0.30	-3.20	-3.00	-4.60
S2	Breakfast	-600.00	-720.00	-144.00	-0.90	-1.80	-0.45	-1.20	-0.90	-1.50
	Lunch	-490.00	-460.00	-192.00	0.70	-1.60	0.00	-0.70	-0.70	-1.30
	Dinner	-290.00	-220.00	-144.00	1.00	-1.00	0.15	-0.30	-0.40	-0.80
	Total	-1380.00	-1400.00	-480.00	0.80	-4.40	-0.30	-2.20	-2.00	-3.60
S3	Breakfast	-450.00	-720.00	-108.00	-0.75	-1.20	-0.45	-0.90	-0.60	-0.90
	Lunch	-290.00	-460.00	-144.00	0.90	-0.80	0.00	-0.30	-0.30	-0.50
	Dinner	-290.00	-220.00	-144.00	1.00	-1.00	0.15	-0.30	-0.40	-0.80
	Total	-1030.00	-1400.00	-396.00	1.15	-3.00	-0.30	-1.50	-1.30	-2.20
S4	Breakfast	-540.00	-720.00	-108.00	-0.90	-1.50	-0.45	-0.90	-0.60	-1.20
	Lunch	-290.00	-460.00	-144.00	0.90	-0.80	0.00	-0.30	-0.30	-0.50
	Dinner	-290.00	-220.00	-144.00	1.00	-1.00	0.15	-0.30	-0.40	-0.80
	Total	-1120.00	-1400.00	-396.00	1.00	-3.30	-0.30	-1.50	-1.30	-2.50
S5	Breakfast	-766.50	-720.00	-131.40	-1.20	-2.10	-0.45	-1.50	-1.20	-1.80
	Lunch	-290.00	-460.00	-144.00	0.90	-0.80	0.00	-0.30	-0.30	-0.50
	Dinner	-290.00	-220.00	-144.00	1.00	-1.00	0.15	-0.30	-0.40	-0.80
	Total	-1346.50	-1400.00	-419.40	0.70	-3.90	-0.30	-2.10	-1.90	-3.10

4.3. Model Comparison

In this section, comparisons are made under the same simulated scenario and both the ADMaM model and conventional MOP model are executed for 50 times separately. The result is shown in Table 10. Under same constraints and with same candidate products from database, recommendation of MOP has a shortage in dairy intake, and recommendation of ADMaM has a shortage in protein and dairy intake. Based on the simulation result, ADMaM has better stability than MOP, and which can be attributed to the price variance of main course in our database. It is more difficult to find solutions closer to optimal with such condition. Therefore the content of product database can be influential to the quality of recommendation result. As mentioned in previous sections, it is possible to fail in finding a satisfactory combination with given budget constraint.

Table 10: Statistics of 50 MOP and ADMaM Simulations

Scenario No.	Model	Statistics	Dietary Energy	Sodium	Caffeine	Grain	Protein	Dairy	Vegetable	Fruit	Fat
S1	MOP	Average	-940.048	-553.402	-438.000	6.686	-3.096	-1.113	-3.113	0.990	3.852
		SD*	241.354	257.385	0.000	2.572	1.608	0.467	0.795	0.970	2.462
	ADMaM	Average	-771.676	-441.851	-438.000	7.354	-4.570	-1.259	-4.199	0.278	2.532
		SD	257.520	221.154	0.000	2.362	0.770	0.259	0.427	0.642	1.659
S2	MOP	Average	-544.064	-551.193	-480.000	6.510	-1.466	-1.101	-1.871	1.684	4.028
		SD	167.556	272.302	0.000	2.471	1.369	0.401	0.561	0.932	2.065
	ADMaM	Average	-387.971	-507.405	-480.000	6.604	-3.654	-1.236	-3.097	1.320	2.552
		SD	148.285	268.554	0.000	1.978	0.853	0.286	0.529	0.849	1.464
S3	MOP	Average	-296.026	-678.068	-360.000	5.680	0.590	-1.181	-0.278	1.848	4.736
		SD	145.805	260.918	0.000	1.927	1.368	0.362	0.598	0.925	2.298
	ADMaM	Average	-280.262	-902.939	-360.000	4.696	-1.734	-1.328	-0.942	1.318	1.794
		SD	108.114	347.665	0.000	1.670	0.855	0.270	0.342	0.575	1.071
S4	MOP	Average	-419.928	-663.716	-360.000	5.602	-0.524	-1.139	-0.438	1.886	4.302
		SD	166.604	337.753	0.000	1.606	1.253	0.345	0.626	0.894	2.426
	ADMaM	Average	-391.036	-687.507	-360.000	5.430	-2.460	-1.239	-1.328	1.488	2.024
		SD	171.757	346.892	0.000	1.703	0.916	0.292	0.549	0.735	1.528
S5	MOP	Average	-941.954	-543.562	-438.000	6.488	-2.866	-1.201	-3.271	1.208	3.844
		SD	256.447	233.248	0.000	2.221	1.206	0.362	0.670	1.009	2.121
	ADMaM	Average	-785.047	-467.859	-438.000	7.568	-4.566	-1.230	-4.010	0.222	1.878
		SD	268.723	320.941	0.000	2.628	0.866	0.290	0.452	0.667	1.948

*Abbreviation for standard deviation

Meanwhile, the ADMaM is embedded with experts' evaluation on every criterion. By considering tangible and intangible criteria, decision makers are supported with a trade-off result based on what they pay and what they get [11]. It is one benefit of proposed model to provide decision makers solutions with better quality and higher perceived value in healthy dietary.

V. Conclusion

The study focuses on an issue of dining out with dietary management. It aims to find a solution in multiple criteria decision-making problem for regular out-eaters in Taiwan.

The ADMaM needs only personal information from decision makers, and it provides satisfactory combinations with coordinating multiple criteria and constraints. This model intends to find equilibrium of personal preference, expert opinions, and suggested daily intakes for six categories of nutrients. If the decision maker's preference is given, this adaptive ADMaM model adjusts preference coefficients to better fit personal needs.

In this study, solutions with given budget constraint may have the possibility of being unable to find a satisfactory combination. Higher budget offers better opportunity for providing variance of food combination and for meeting all criteria. Another problem this study has experienced is that many products provided by chain restaurant/store has insufficient nutrients but with excessive dietary energy. If the decision maker follows recommended combination, he/she can have nutrient intakes closer to the suggested amount. Based on the simulation result, ADMaM performs with better stability and better realization in the concept of healthy dietary. The ADMaM solution offers dietary combinations which can be perceived with higher value given the same constraint of budget. If the product database can be further expanded, our proposed model can be more practical for regular out-eaters.

The simulation result by taking only expert opinions in this study shows the potential problem that without thorough understanding of products and restaurants/stores, even the most recommended store from AHP evaluation matrix may lead to a result of dissatisfaction. ADMaM counts opinions from both experts and regular out-eaters, with an adaptive mechanism to keep the AHP matrix updated with market information and real user feedback, provides out-eaters a healthy and efficient way to deal with their dining issue.

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Jung-Bin Li. Jung-Bin Li is an assistant professor at the Department of Statistics and Information Science, Fu Jen Catholic University (Taiwan). He received his B. B. A. in Computer Science from Soochow University (Taiwan) in 1993, and his Master's degree in Information Management from London School of Economics and Political Science (United Kingdom) in 1996. His Ph.D. degree was received from National Chiao Tung University (Taiwan) in 2006. His research interests include data mining, forecasting methods, decision support systems, mobile commerce, and statistical information systems.

Wei-Jan Huang. Wei-Jan Huang received Bachelor of Science in Mathematics (Applied Mathematics Section) from Fu Jen Catholic University, New Taipei City, Taiwan R.O.C (2012) and Master of Science in Applied Statistics (Statistics and Information Science) from Fu Jen Catholic University, New Taipei City, Taiwan R.O.C (2014). He has published papers in one national conference and one international conference in Management Information Systems.