



Optimizing Menu Planning for Children with Autism Using Improved Multi-Goal Programming Model

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Abstract

Menu planning for every individual is essential to obtain a balanced and healthy food intake for growth and development. Children with Autism Spectrum Disorders (ASD) face more feeding difficulties than their peers due to neurodevelopmental disorders such as social skills problems and repetitive behaviors. They also tended to refuse or be selective for certain food intakes. Proper menu planning for children with ASD is important to maintain their overall well-being and mitigate autism-related dietary issues. The manual menu planning for children with ASD does not consider proper nutritional intake, food variation, or total cost minimization. Currently, the application of mathematical modelling for menu planning in children with ASD is limited. Thus, this study aims to explore the extent to which the optimization approach can solve the menu planning problem with more than one objective. Finally, this research constructed daily menu planning for children with ASD, which indicates the feasibility of utilizing the Improved GP (IGP) model compared to the Goal Programming model (GP) in terms of the value for the deviational variables for the unachieved goals. The unachieved deviational variables by IGP model for Day-2 had decreased by 17.69% and by 34.43 % on Day-3. The total cost of the IGP model is also less than RM 0.50 of the GP model.

Keywords: autism; goal programming; menu planning; optimization;

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1. Introduction

The issue of menu planning has been one of the great interests in the health area due to the importance of proper nutrition for the body. Proper menu planning is very essential to prevent malnutrition or inadequate nutrient intake which also to prevent the body from being infected with unwanted diseases [1]. The individual's health condition contributes to the planning process of the proper menu planning [2]. Previously, George J. Stigler in 1945, is the pioneer of the menu planning problem and known as the Father of Diet Problem with trial-and-error technique [3]. The optimization of menu planning has been classified as NP-hard problem because it deals with thousands of variables, and it may involve hundreds of constraints in the optimization methods [4]. The selection of food

generally ranges by their cost, the nutrient content, flavour, demographics, culture, religion, health, social or influenced by the media and environmental concerns [5].

Children with Autism Spectrum Disorders (ASD) who had impairment in social skills and repetitive behaviors usually having significantly more meal intake difficulties than their peers [6]. In addition, the presence of the core symptoms such as repetitive behavior, motor abnormalities, intellectual disability, sleep disorders and gastrointestinal (GI) may affect the proper nutrient intake during the mealtime [7]. Proper menu planning for ASD children is important to maintain their overall wellbeing to mitigate the autism symptoms as well as to avoid the gut issues [8]. The cost of the food, nutrient intake fulfilment and menu verification are some of the

goals that should be achieved to acquire the optimal or the best combination of menu by minimizing or maximizing the objective function [9]. The application of mathematical techniques to design the menu planning is not new to the scientific literature since the groundwork of menu planning by Stigler [10]. Besides, menu planning which is a specific planning type is considered as a complex task that some researchers have attempted to model and computerize since the early 1960s [11].

The menu planning for any institution may encounter difficulties in making the right decisions to meet the nutrient requirement within the allocated budget. Mathematical techniques such as Linear Programming have been widely used for menu planning optimizations which considers menu planning with several type of constraints and objective functions [12]. There are also different techniques used in the operational research area to solve various diet problems with usually involves more than one objective [13]. The menu planning for the ASD children may involve more than one objective to be solved simultaneously such as to achieve the level of nutrient intake, minimize the cost, to maximize the food selection and to avoid the repetition of meals [14]. Thus, this paper intended to explore the application of optimization approach to solve menu planning problem for the ASD children that also considers type of menus suggested by the ASD centre which will not trigger the ASD symptoms among the children [15]. This also will help smooth activities of any activity sessions at the centre as well as to promote better overall well-being for the children.

The creation of menu planning is complicated to be solved by manual process as many factors involved in the decision-making process. Initially, Trial-and-error optimization methods have been used to solve the menu planning problem [13]. However, this method cannot solve complex menu planning problems since the process are typically created manually [16]. The evolution of the mathematical model and computer technology into this area is widely enhanced further since the study by Balintfy in 1964 [17]. One of the approaches that lies under the Operational Research (OR) area is the optimization approaches with three

main techniques which are linear programming (LP), integer programming (IP) and mix integer programming (MIP) [18]. The optimization model will find the optimal solutions for the decision variables under certain constraints which are either maximizing or minimizing the objective functions [19]. Thus, the menu planning through optimization method is to fulfil the nutrient intake, daily food group requirement as well as achieving the cost minimization for the menu in a defined geographic area and for certain group population [20].

Based on the literature search, the basic approach for diet optimization approach is LP with three main elements which are objective function, constraints and the decision variables [21]. This technique will seek the optimal solution which is either to maximize or minimize the objective function for limited set of constraints to evaluate the quantitative decisions [22]. LP is a influential technique for solving management problems that has been extensively applied in financial planning, banking, transportation, engineering strategy, scheduling, and many other applications [23]. Integer programming (IP) on the other hand, acts equally as the LP model but the decision variables are restricted for integer value [24]. Mixed-integer-linear programming (MILP) offers problems of greater complexity and provides more choices for the selection of food groups in terms of constraints [25]. The real-life situation will be easier, more comfortable, and more economic with the aid of LP techniques as the problems will get optimum achievement from the restricted resources [26]. The real-life problems, at first should be modeled into linear programming models that consist of linear equations or inequalities from a certain number of resources [27]. The decision variables in the LP model are the important factors that can be determined by the decision makers to obtain the optimal solutions under the defined objectives [26]. The constraints such as the nutrient needs, cost of the menu and the food group requirement in the LP model should be respected to attain the defined optimal solution [28]. Table 1 shows the summary of a previous study that applied optimization techniques in menu planning.

Table 1. The Previous Study on Menu Planning by Optimization Techniques

Reference	Objective Functions	Decision Variable(s)	Constraints	Focus	Optimization Technique
[29]	Minimize cost	Food items	Nutrients and food group	Menu planning for stroke patients	LP and IP
[24]	Maximize vitamin D intake	The concentration of Vitamin D, Food items	Food group	Optimizing vitamin D intake from multiple food groups	MILP
[30]	Minimize cost	Portions of carbohydrate, protein, fruits and vegetables	Nutrients, food group and calory intake	Optimize a weekly meal plan for college students	LP
[31]	Minimize cost	Food items	Nutrients	Develop a model for campus restaurant's menu	LP
[32]	Minimize cost	Food items	Nutrients, food expenditure and food group	Develop a minimum cost healthy meal plan for adult	MILP
[16]	Minimize cost	Food items	Nutrients and food group	Menu planning for sinusitis patient	LP and IP

The optimization problems with multiple objectives that are conflict with each other will be solved using multi-objectives optimization method such as goal programming (GP), weighted sum approach and the epsilon constraint (ϵ -constraint) methods [33]. GP is the multi-objective optimization tool that is the extension of LP to solve multiple and conflicting goals problems [34]. It is also used to minimize deviations between the goals and the achievement for a complex menu planning problem [35]. Additionally, GP also has been widely used in many other applications that involved multiple goals such as in the study of library acquisition allocation [36], production planning [37], supplier selection [34], financial management [39], feeding blend for livestock [40] and many others. There are also the studies on the menu planning optimization by the application of GP as in [41] – [43]. The menu planning for the ASD children may involve more than one objective such as to achieve the level of nutrient intake, minimize the cost, to maximize the food selection and to avoid the repetition of meals [6].

By GP model, there are often multiple goals that are conflicting and will be achieved only at the expense of other goals. However, according to [44], the summation and subtraction of deviations of multi-dimensional values may be biased on the goal/s with higher values of coefficients. Thus, this study will utilize the Improved Goal Programming Model (IGP) for the optimization of menu planning which involves multiple objectives.

2. Methods

This paper will highlight the application of GP and IGP model as an optimization tool for the ASD children's menu planning and the development of the model is shown Figure 1.

The methodology starts with identifying the decision variables, the constraints, and the objectives functions. Then, the steps continue with developing the GP and IGP model and executing the model by LINGO Software. The construction of the menu for the next day is obtained by deleting the menu that has been selected in the previous day except for plain water, plain rice, and fresh milk. The data collections were from both primary and secondary sources where the primary data has been obtained from the dietician, parents and the ASD center. The secondary data on the other hand has been obtained from Reference Nutrient Intake (RNI 2017) [45] for the limits of nutrients for Malaysian children ages from 7-9 years old while the nutrient content of each menu was gained from Malaysia Food Composition website (MYFCD). The cost of each menu and the budget allocation is wide-ranging across the states due to cost of living. Hence, this study aims to minimize the allocated budget while at the same time fulfil the daily requirements of nutrients and food groups for the children. The decision variables involved in this study are various Malaysian food that consider the food which is suitable for the ASD children. Then,

the combinations of menu will be displayed in the menu list according to six categories of food group. The parameters are the nutritional content that are essential for the ASD children such as Energy, Fat, Calories, and essential vitamins together with the price for the standard size of menu.

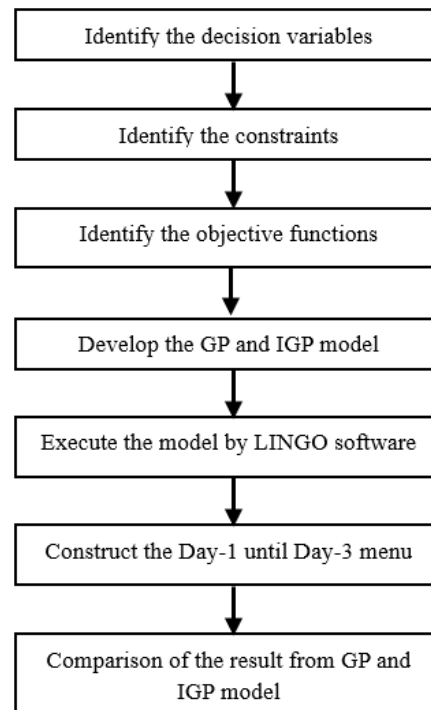


Figure 1. The Model Development by GP and IGP Model for the Menu Planning Optimization

The lower and upper limit for every nutrient is shown on Table 2. The assumption to be clarified in this study includes standardized portions of the menu intake while the nutrients contained in each menu are assumed to be consumed as a whole unit.

Table 2. The Recommended Nutrient Intake and Boundaries for Children Aged 7-9 years Old (RNI2017)

Nutrients	Lower bound (L)	Upper bound (U)
Energy (kcal)	1410	1970
Protein (g)	23	-
Fats (g)	45	68
Carbohydrate (g)	193.88	344.75
Calcium (mg)	1000	-
Iron (mg)	6	9
Niacin B3 (mg)	12	-
Vitamin A (μ g)	500	-
Vitamin B1 (mg)	0.9	-
Vitamin B2 (mg)	0.9	-
Vitamin C(mg)	35	-

There are 90 menu selections that incorporate the aspects of nutrition and sensory attributes of the food in terms of the domain taste of the food which are sweet, sour, salty and umami under seven types of food groups as shown in Table 3. The food groups include cereal meal based, cereal flour based, meat, sea food, fruit, vegetables, beverages and miscellaneous with a total of 16 daily menus.

The information on the current daily budget, the daily menu and cost per serving for each meal had been collected from the ASD center and a dietitian through interview sessions where the center has set the budget of RM25 per day. Table 4 shows the type of daily meals which are breakfast, morning tea, lunch, and dinner with the number of menus that should be served during that mealtime.

Table 3. Type of Food Group and the Daily Requirements

Food Groups	Number of Requirements per Day
Beverages	5 *including 3 plain water and 1 fresh milk
Cereal Meal Based	3 *including 2 plain rice
Cereal-Flour Based	1
Meat/Seafood	2
Fruit	2
Vegetables	2
Miscellaneous	1
Total	16

Table 4. Type of Menus for Each Mealtime

	Cereal Based	Meal	Cereal Based	Flour	Meat/Seafood	Fruit	Vegetables	Miscellaneous	Beverages
Breakfast	1								1(Fresh Milk)
Morning Tea			1						1(Plain Water)
Lunch	1(Plain Rice)				1		1		1(Plain Water)
Evening Tea						1		1	1
Dinner	1(Plain Rice)				1	1	1		1(Plain Water)

2.1 The General Equation for ASD Children Menu Planning by GP Model

The GP model is expected to minimize the sum of the deviations of the recommended daily nutrients needed by the ASD children as well as the total cost of the menus. The GP model also had assumed equal weights to different deviations from the nutrient requirements and the cost of the daily menus as well. The negative and positive deviational variables representing deviations from the i^{th} goals are denoted by $DN(i)$ and $DP(i)$ where the lower limit of the nutrient's constraints should obtain $DP = 0$ while for the upper limit of the nutrient's constraints should obtain $DN = 0$. Thus, the GP model formulation as in [39] is as shown in Equations 1-3.

Minimize

$$Z = \sum_{i=1}^m DN(i) + DP(i) \quad (1)$$

Subject to:

Hard constraint

$$\sum_{j=1}^n a_j X_j (\leq, =, \geq) b_i \quad (2)$$

Soft constraint

$$\sum_{j=1}^n a_j X_j + DN(i) - DP(i) = c_i \quad (3)$$

In this equation, X_j is the decision variable for j^{th} food items, where $X_j = 1$ if the item is selected and $X_j = 0$ otherwise. The term a_j represents the input parameter of cost and nutrients of each food item. The positive deviational variable, $DP(i)$ is the amount of the by which i^{th} goals are overachieved and the negative deviational variables $DN(i)$ is the amount of by which i^{th} goals are underachieved. The parameter c_i is the target or aspiration level of the nutrient nutrients associated with i^{th} constraint while b_i is the right-hand side of the hard constraints such as the total daily number of each food group. The index i ranges from 1 to m , representing the number of deviational variables,

while j ranges from 1 to n , representing the number of food items.

The general equations of the soft constraints are as shown in Equation 4.

$$L_i \leq \sum_{j=1}^{90} a_j x_j \leq U_i \quad (4)$$

L_i is the lower bound for nutrient i while U_i is the upper bound for nutrient i . Then, the deviation variables will be included the constraints for both upper and lower equations as shown in Equation 5 and 6.

$$\sum_{j=1}^{90} a_j x_j + DN(i) - DP(i) = L_i \quad (5)$$

$$\sum_{j=1}^{90} a_j x_j + DN(i) - DP(i) = U_i \quad (6)$$

$$x_1 + x_2 + x_3 + x_4 + x_5 + \dots + x_{90} + DN(i) - DP(i) = U_i$$

Thus, $DN(i)$ from Equation 5 and $DP(i)$ from Equation 6 will be minimized in the objective function. The cost and the macronutrients, which are energy, carbohydrates, protein, and fats are formulated as hard constraints while the micronutrients which are calcium, Iron, Vitamin A, Vitamin C, Vitamin B1, Vitamin B2 and Vitamin B3 are formulated as soft constraints.

2.2 Goals

The set of soft constraints are then constructed in the model formulation as the goals.

The first goal is to maximize the daily value of Calcium to be greater than 1000 mg. The goal constraint and the deviational variable to be minimized are as shown in Equation 7.

$$\sum_{i=1}^{90} a_j x_j + DN1 - DP1 = 1000 \quad (7)$$

$DN1$ is minimized.

The second goal is to maximize the daily value of Vitamin C to be greater than 35 mg. The goal constraint and the deviational variable to be minimized are as shown in Equation 8.

$$\sum_{i=1}^{90} a_j x_j + DN2 - DP2 = 35 \quad (8)$$

DN2 is minimized.

The third goal is to achieve the daily lower limit of Iron to be greater than 6 mg. The goal constraint and the deviational variable to be minimized are as shown in Equation 9.

$$\sum_{i=1}^{90} a_j x_j + DN3 - DP3 = 6 \quad (9)$$

DP3 is minimized.

The fourth goal is to achieve the daily upper limit of Iron to be less than 9 mg. The goal constraint and deviational variable to be minimized are as shown in Equation 10.

$$\sum_{i=1}^{90} a_j x_j + DN4 - DP4 = 9 \quad (10)$$

DP4 is minimized.

The fifth goal is to achieve the value of Vitamin B1 to be more than 0.9 mg. The goal constraint and the deviational variable to be minimized are as shown in Equation 11.

$$\sum_{i=1}^{90} a_j x_j + DN5 - DP5 = 0.9 \quad (11)$$

DN5 is minimized.

The sixth goal is to achieve the daily value of Vitamin B2 to be more than 0.9 mg. The goal constraint and the deviational variable to be minimized are as shown in Equation 12.

$$\sum_{i=1}^{90} a_j x_j + DN6 - DP6 = 0.9 \quad (12)$$

DN6 is minimized.

The seventh goal is achieving the value of daily value of Vitamin B3 to achieve more than 12 mg. The goal constraint and the deviational variable to be minimized are as shown in Equation 13.

$$\sum_{i=1}^{90} a_j x_j + DN7 - DP7 = 12 \quad (13)$$

DN7 is minimized.

The eighth goal is to achieve the daily value of Vitamin A to be more than 500 µg. The goal constraint and the deviational variable to be minimized are as shown in Equation 14.

$$\sum_{i=1}^{90} a_j x_j + DN8 - DP8 = 500 \quad (14)$$

DN8 is minimized.

The GP model has been improved in [44] by scalarizing the objective function. Thus, the deviations in IGP model are free of dimensions as shown in Equation 15.

$$Z = \sum_{i=1}^m (DN(i) + DP(i))/c_i \quad (15)$$

Then, the other constraints are referred to Equations 2 and 3.

3. Results and Discussions

LINGO software has been used to execute the model. The optimized menu ensures that the nutritional needs are effectively met, which also considers the cost, nutrient requirements, and food varieties. The menu involves seven food groups for five times serving which are breakfast, morning tea, lunch evening tea and dinner. The GP model is aimed to minimize the total deviations of goals from the specified target. In Table 5, the values of the objective function or the total value of the deviational variables for the goals are zero for both GP and IGP models for Day-1 which indicate that all the goal has been fully achieved by both models.

Table 5. The Deviational Variables Values for Day-1 by GP and Improved GP Model

Nutrients	Boundaries	GP Model	IGP Model
		The Deviational Variables	
Calcium (Goal 1)	≥ 1000	DN1=0.00	DN1=0.00
Ascorbic Vitamin C (Goal 2)	≥ 35	DN2=0.00	DN2=0.00
Iron (Goal 3)	Lower bound ≥ 6	DN3=0.00	DN3=0.00
Iron (Goal 4)	Upper bound ≤ 9	DN4=0.00	DN4=0.00
Vitamin B1 (Goal 5):	≥ 0.9	DN5=0.00	DN5=0.00
Vitamin B2 (Goal 6):	≥ 0.9	DN6=0.00	DN6=0.00
Vitamin B3 (Goal 7):	≥ 12	DN7=0.00	DN7=0.00
Vitamin A (Goal 8)	≥ 500	DN8=0.00	DN8=0.00
Total Value of Deviational Variables		0	0

Table 6 and Figure 2 show the total values for the deviational variables where the value for GP model is 3.9 and a reduced value for IGP model which is 3.21 for Day-2. Goal 4 from GP model shows the value for DP4 is of 3.9 indicating that the upper limit of Iron has exceeded about 3.9 mg from 9 mg. Then, Goal 4 under IGP model indicates that Iron has exceeded about 3.1 mg from 9 mg while Vitamin B under Goal 5 has exceeded 0.11 mg from 0.9 mg.

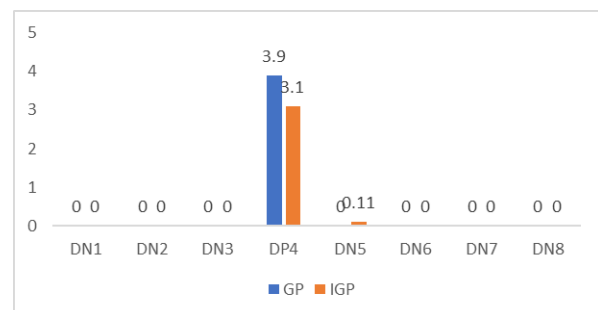


Figure 2. The Deviational Variable Value for GP and IGP Model for Day-2

Table 6. The Deviation Variables Values for Day-2 by GP and Improved GP Model

Nutrients	Boundaries	GP Model The Deviation Variables	IGP Model
Calcium (Goal 1)	≥ 1000	DN1=0.00	DN1=0.00
Ascorbic Vitamin C (Goal 2)	≥ 35	DN2=0.00	DN2=0.00
Iron (Goal 3)	Lower bound ≥ 6	DN3=0.00	DN3=0.00
Iron (Goal 4)	Upper bound ≤ 9	DP4=3.9	DP4=3.1
Thiamine (Vitamin B1) (Goal 5):	≥ 0.9	DN5=0.00	DN5=0.11
Riboflavin (Vitamin B2) (Goal 6):	≥ 0.9	DN6=0.00	DN6=0.00
Niacin (Vitamin B3) (Goal 7):	≥ 12	DN7=0.00	DN7=0.00
Vitamin A (Goal 8)	≥ 500	DN8=0.00	DN8=0.00
Total Value of Deviation Variables		3.9	3.21

Table 7 and Figure 3 show the values of the deviational variables where the total value is 136.53 for GP model and a reduced value for IGP model which is 88.71 for Day-3.

Table 7. The Deviation Variables Values for Day -3 by GP and Improved GP Model

Nutrients	Boundaries	GP Model The Deviation Variables	IGP Model
Calcium (Goal 1)	≥ 1000	DN1=125	DN1=75
Ascorbic Vitamin C (Goal 2)	≥ 35	DN2=0.00	DN2=0.00
Iron (Goal 3)	Lower bound ≥ 6	DN3=0.00	DN3=0.00
Iron (Goal 4)	Upper bound ≤ 9	DP=10.3	DP=10.8
Thiamine (Vitamin B1) (Goal 5):	≥ 0.9	DN5=0.13	DN5=0.11
Riboflavin (Vitamin B2) (Goal 6):	≥ 0.9	DN6=0.00	DN6=0.00
Niacin (Vitamin B3) (Goal 7):	≥ 12	DN7=1.1	DN7=2.8
Vitamin A (Goal 8)	≥ 500	DN8=0.00	DN8=0.00
Total Value of Deviation Variables		135.3	88.71

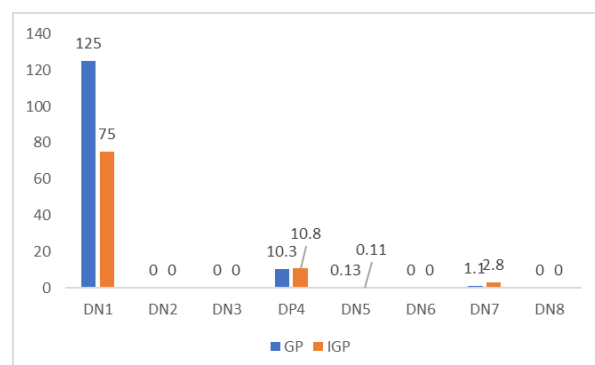


Figure 3. The Deviation Variable Value for GP and IGP Model for Day-3

IGP performed better in Day-3 because of the major impact of the value of the unachieved deviational variables of Calcium which showed DN1=125 by GP model and DN1=75 by IGP model. DN1=125.00 from GP model indicates that the value of Calcium is less 125.00 mg from 1000 mg while DP4=10.30 indicates that the value of Iron is more than 10.30 mg from 9 mg. DN5=0.13 indicates that the value Vitamin B1 is less than 0.13 mg from 0.9 mg and DN7=1.10 indicates that the value of Vitamin B3 is less than 1.0 from 12 mg.

Then, by IGP model, DN1= 75 indicates that the value of Calcium is less 75 mg from 1000 mg, DP4=10.80 indicates that the value of Iron is more than 10.80 mg from 9 mg, DN5=0.11 indicates that the value Vitamin B1 is less than 0.11 mg from 0.9 mg and DN7=1.10 indicates that the value of Vitamin B3 is less than 1.1mg from 12mg.

Table 8. The Menu and the Total Cost for 3 Days by GP Model

Meals	DAY 1	DAY 2	DAY 3
Breakfast	Fresh cow milk Chicken rice	Fresh cow milk Rice coconut milk	Fresh cow milk Noodle (soup)
Morning Tea	Plain water Alphabet shaped biscuit	Plain water Peanut coconut biscuit	Plain water White bread
Lunch	Plain water Plain rice Shaped and fried chicken meat Cucumber Milo	Plain water Plain rice Fried chicken (various portions) Carrot Milk powder, skim Pear (yellow)	Plain water Plain rice Chicken curry French bean Soybean milk, unsweetened Orange
Evening Tea	Golden banana Pizza with pepperoni, beef	Fish crackers (fried)	Banana, fried
Dinner	Plain water Plain rice Hen egg Chestnut banana Bean-string	Plain water Plain rice Chicken frankfurter Mango Spinach	Plain water Plain rice Chicken fried Green pear Red spinach
Total Number of Meal	16	16	16
Total Cost	RM 24.80	RM24.30	RM24.90
Total Cost =	RM 74		

Then, Table 8 and Table 9 show the menus and total cost for 3 days by both GP and IGP model. The total cost for the 3 days is RM 74 by GP model and a reduced value for IGP model which is RM 73.50. This shows that IGP model has given better results in terms of obtaining less total value for the deviational variables and the total cost of the menu planning for the ASD children. The menus will then be rotated for every 3 days due to the availability of menu variables.

Table 9. The Menu and the Total Cost for 3 Days by IGP Model

Meals	DAY 1	DAY 2	DAY 3
Breakfast	Fresh cow milk Chicken rice	Fresh cow milk Noodle (soup)	Fresh cow milk Rice, coconut milk
Morning Tea	Plain water Swiss roll cake Chocolate Flavor	Plain water White bread	Plain water Keria
Lunch	Plain water Plain rice Fried chicken	Plain water Plain rice Hen egg (whole)	Plain water Plain rice Chicken curry
Evening Tea	Cucumber Milo Golden Banana Banana, Fried	Bean string Milk powder, scheme Mango	French bean Soya bean milk, Unsweetened Green pear
Dinner	Plain water Plain rice Shaped and fried chicken meat Carrot Chestnut banana	Plain water Plain rice Chicken, frankfurter Spinach Yellow pear	Plain water Plain rice Fried chicken Red spinach Orange
Total Number of Meal	16	16	16
Total Cost	RM 24.00	RM 25.00	RM 24.50
Total Cost=	RM 73.50		

4. Conclusions

Menu planning will become complicated, inefficient, inaccurate, lacks in variety and time consuming if it is done manually. Thus, the aid of optimization techniques for the ASD children menu planning can significantly improve the dietary and health outcomes for the ASD children to live a better life. This will offer practical solutions for families, caregivers and the ASD children themselves. In addition, this study will contribute valuable knowledge to the field of nutrition and autism environment and potentially influence policy and practice.

The IGP model with the execution by LINGO software has successfully obtained the proper menu that considers cost minimization, fulfils the nutrients requirements, and obtains menu variations. The IGP model is also better than the GP model in term of reducing the total value of the deviational variables of the unachieved goals and the total cost as well. The unachieved deviational variables by IGP model for Day-2 had decreased by 17.69% and by 34.43 % for Day-3 when compared to GP model. In addition, the cost executed by IGP model shows 0.67% of decrement. Thus, it shows that mathematical model can be used for decision maker to plan and obtain optimized menu planning for certain target group. It is recommended for future work to apply other variants of GP model and apply integrated models. The Multi-

Criteria Decision Method (MCDM) is also applicable to solve this kind of problem with more complicated constraints which also involve more data.

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References

- [1] J. M. Ramos-Pérez, G. Miranda, E. Segredo, C. León, and C. Rodríguez-León, "Application of multi-objective evolutionary algorithms for planning healthy and balanced school lunches," *Mathematics*, vol. 9, no. 1, pp. 1–24, Jan. 2021, doi: 10.3390/math9010080.
- [2] L. Z. Sheng and S. Sufahani, "Optimal Diet Planning for Eczema Patient Using Integer Programming," *Journal of Physics: Conference Series*, vol. 995, no. 1. 2018, doi: 10.1088/1742-6596/995/1/012049.
- [3] S. F. Sufahani, and Z. Ismail, "A diet planning model for Malaysian boarding school using zero-one integer programming," *Prosiding Seminar Kebangsaan Aplikasi Sains Dan Matematik*, Oct. 2013.
- [4] B. K. Seljak, "Computer based dietary menu planning," *Journal of Food Composition and Analysis*, vol. 22, pp. 414–420, 2009.
- [5] K. E. Drummond and L. M. Brefere, *Nutrition for Foodservice and Culinary Professionals*, 8th ed. John Wiley and Sons Inc, 2014.
- [6] M. Esposito, P. Mirizzi, R. Fadda, C. Pirollo, O. Ricciardi, M. Mazza, and M. Valenti, "Food Selectivity in Children with Autism: Guidelines for Assessment and Clinical Interventions," *International Journal of Environmental Research and Public Health* vol. 20, no. 6, 2023, doi: 10.3390/ijerph20065092.
- [7] S. A. Cermak, C. Curtin, and L. G. Bandini, "Food Selectivity and Sensory Sensitivity in Children with Autism Spectrum Disorders," *Journal of the American Dietetic Association*, vol. 110, no. 2, pp. 238–246, Feb. 2010, doi: 10.1016/j.jada.2009.10.032.
- [8] F. Fulceri, M. Morelli, E. Santocchi, H. Cena, T. Del Bianco, A. Narzisi, S. Calderoni, and F. Muratori, "Gastrointestinal symptoms and behavioral problems in preschoolers with Autism Spectrum Disorder," *Digestive and Liver Disease*, vol. 48, no. 3, pp. 248–254, Mar. 2016, doi: 10.1016/j.dld.2015.11.026.
- [9] J. Y. Tee, and S. F. Sufahani, "Vegetarian Menu Planning Through Optimization Method: An Overview," *ACCESS Online Journal IJACSSEJournal-International Journal of Advanced Computer Systems and Software Engineering*, vol. 2, pp. 30–36, 2021.
- [10] S. Sufahani, and Z. Ismail, "A new menu planning model for Malaysian secondary schools using optimization approach," *Applied Mathematical Sciences*, vol. 8, pp. 149–152, 2014, doi:10.12988/ams.2014.49725.
- [11] F. Martos-Barrachina, L. Delgado-Antequera, M. Hernández, and R. Caballero, "An extensive search algorithm to find feasible healthy menus for humans," *Operational Research*, vol. 22, no. 5, 2022, doi: 10.1007/s12351-022-00702-4.
- [12] D. Basyuk, I. Levytska, L. Ivchenko, I. Semenyshyna, and S. Koliadenko, "Optimization of the menu for institutions of restaurant industry based on mathematical modelling methods," *Intellectual Economics*, vol. 14, no. 1, pp. 130–143, 2020, doi: 10.13165/IE-20-14-1-08.
- [13] L. Donkor, E. Essien, and N. S. Afrifah, "A Systematic Review of Linear Programming Techniques as Applied to Diet Optimisation and Opportunities for Improvement," *Journal of Optimization*, vol. 2023, 2023, doi: 10.1155/2023/1271115.
- [14] Z. Taha and K. A. Abdalhai, "A review of the efficacy of the dietary intervention in autism spectrum disorder," *Open Access Macedonian Journal of Medical Sciences*, vol. 9, pp. 88–94, 2021, doi: 10.3889/oamjms.2021.5743.

- [15] G. Petitpierre, A. C. Luisier, and M. Bensafi, "Eating behavior in autism: senses as a window towards food acceptance," *Current Opinion in Food Science*, vol. 41, pp. 210–216, 2021, doi: 10.1016/j.cofs.2021.04.015.
- [16] B. I. Osman and S. F. Sufahani, "Nutritious Menu Planning for Sinusitis Patient in Malaysian Through Optimization Approach," *Lecture Notes in Networks and Systems*, vol. 348, pp. 31–44, 2022, doi: 10.1007/978-981-16-7597-3_3.
- [17] L.M Lancaster, "The history of the application of mathematical programming to menu planning," *European Journal of Operational Research*, vol. 57, pp. 339–347, 1992.
- [18] C. Türkmenoğlu, A. Ş. Etaner Uyar, and B. Kiraz, "Recommending healthy meal plans by optimising nature-inspired many-objective diet problem," *Health Informatics Journal*, vol. 27, no. 1, 2021, doi: 10.1177/1460458220976719.
- [19] R. Alaini, R. Rajikan, and S. M. Elias, "Diet optimization using linear programming to develop low-cost cancer prevention food plan for selected adults in Kuala Lumpur, Malaysia," *BMC Public Health*, vol. 19, 2019, doi: 10.1186/s12889-019-6872-4.
- [20] H. Okubo, S. Sasaki, K. Murakami, T. Yokoyama, N. Hirota, A. Notsu, M. Fukui, and C. Date, "Designing optimal food intake patterns to achieve nutritional goals for Japanese adults through the use of linear programming optimization models," *Nutrition Journal*, vol. 14, no. 1, 2015, doi: 10.1186/s12937-015-0047-7.
- [21] L. K. Gautam, M. L. K. Gautam, and V. S. Gulhane, "Optimization Methods and its Application in Nutritional Diet," [Online]. Available: <https://www.researchgate.net/publication/357048291>, 2020.
- [22] V. D. G. Balcita, A. T. A. Bejar, T. P. P. Goy, R. K. C. Billones, and E. P. Dadios, "Optimizing the Allocation of Renewable Energy Generation and Energy Consumption of Power Plants in the Philippines using Linear Programming," in *2021 IEEE 13th Int. Conf. on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM)*, 2021, doi: 10.1109/HNICEM54116.2021.9732024.
- [23] R. Kunwar and H. P. Sapkota, "Introduction to Linear Programming Problems with Some Real-Life Applications," *European Journal of Mathematics and Statistics*, vol. 3, no. 2, pp. 21–27, 2022, doi: 10.24018/ejmath.2022.3.2.108.
- [24] S. Sengupta, T. Christensen, G. Ravn-Haren, and R. Andersen, "Vitamin D Food Fortification Strategies on Population-Based Dietary Intake Data Using Mixed-Integer Programming," *Foods*, vol. 12, no. 4, 2023, doi: 10.3390/foods12040698.
- [25] M. Padovan, F. R. de Senna, J. K. Kimura, S. T. Nascimento, A. C. Moretti, and C. D. Capitani, "Optimized menu formulation to enhance nutritional goals: design of a mixed integer programming model for the workers' food program in Brazil," *BMC Nutrition*, vol. 9, no. 1, 2023, doi: 10.1186/s40795-023-00705-0.
- [26] A. Briend, N. Darmon, E. Ferguson, and J. G. Erhardt, "Linear Programming: A Mathematical Tool for Analyzing and Optimizing Children's Diets During the Complementary Feeding Period," 2003.
- [27] Y. M. R. Aboelmagd, "Linear programming applications in construction sites," *Alexandria Engineering Journal*, vol. 57, no. 4, pp. 4177–4187, 2018, doi: 10.1016/j.aej.2018.11.006.
- [28] M. Ali, S. Sufahani, and Z. Ismail, "A new diet scheduling model for Malaysian school children using zero-one optimization approach," *Global Journal of Pure and Applied Mathematics*, vol. 12, no. 1, 2016.
- [29] M. A. Jamaludin and S. F. Sufahani, "Nutritious Menu and Nutrient Planning for Avoiding Stroke Disease by Using Optimization Technique," *Lecture Notes in Networks and Systems*, vol. 348, pp. 45–56, 2022, doi: 10.1007/978-981-16-7597-3_4.
- [30] A. J. L. Pe, J. K. Coaching, S. G. D. Yeung, W. Akeboshi, and R. K. C. Billones, "Cost Optimization for Weekly Meal Planning of College Students Based on Calorie Constraints using Linear Programming (LP) Method," in *2022 IEEE 14th Int. Conf. on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM)*, 2022, doi: 10.1109/HNICEM57413.2022.10109597.
- [31] M. D. S. Spak and J. C. Colmenero, "University restaurants menu planning using mathematical modelling," *Journal of Food and Nutrition Research*, vol. 60, no. 1, 2021.
- [32] A. Coleen, S. De Leon, C. T. Ninobla, N. Joyce, S. Sibal, K. Mile, J. B. Yu, E. Gabriel, and C. Bucu, "Low-cost Dietary Plan for COVID-19 Immunity Response Using Mixed-Integer Linear Programming," 2022.
- [33] R. Abejón, L. Batlle-Bayer, J. Laso, A. Bala, I. Vazquez-Rowe, G. Larrea-Gallegos, M. Margallo, J. Cristobal, R. Puig, P. Fullana-I-palmer, and R. Aldaco, "Multi-objective optimization of nutritional, environmental and economic aspects of diets applied to the Spanish context," *Foods*, vol. 9, no. 11, 2020, doi: 10.3390/foods9111677.
- [34] F. De Oliveira, N. M. P. Volpi, and C. R. Sanquetta, "Goal programming in a planning problem," *Applied Mathematics and Computation*, vol. 140, no. 1, pp. 165–178, 2003, doi: 10.1016/S0096-3003(02)00220-5.
- [35] K. Wise and D. E. Perushek, "Goal Programming as a Solution Technique", 2000. [Online]. Available: https://trace.tennessee.edu/utk_libpub/5.
- [36] N. Hassan, D. F. Azmi, T. S. Guan, and L. W. Hoe, "A goal programming approach for library acquisition allocation," *Applied Mathematical Sciences*, vol. 7, no. 137–140, pp. 6977–6981, 2013, doi: 10.12988/ams.2013.310574.
- [37] I. Hasbiyati, R. Desri, and M. D. H. Gamal, "Pre-Emptive Goal Programming Method for Optimizing Production Planning," *BAREKENG: Jurnal Ilmu Matematika Dan Terapan*, vol. 17, no. 1, pp. 0065–0074, 2023, doi: 10.30598/barekengvol17iss1pp0065-0074.
- [38] N. Rasyida, M. Rashid, B. A. Halim, N. Hassan, I. Shah, M. Zawawi, and H. Aris, "Supplier Selection using Zero-One Goal Programming Method," *Journal of Advanced Research in Dynamical and Control Systems*, vol. 11, 2019, [Online]. Available: <https://www.researchgate.net/publication/338987352>.
- [39] W. S. Lam, P. F. Lee, and W. H. Lam, "Optimization on the Financial Management of Construction Companies with Goal Programming Model," *IOCMa 2023*, p. 29, 2023, doi: 10.3390/iocma2023-14420.
- [40] N. Rasyida, M. Rashid, N. M. Lip, F. Farhayu, M. Salim, N. F. Kamazan, S. Nor, and A. M. Latib, "Feeding Blend Optimization for Livestock by Using Goal Programming Approach," *Malaysian Journal of Computing*, vol. 5, no. 2, pp. 495–503, 2020.
- [41] I. Jridi, B. Jerbi, and H. Kamoun, "Menu planning with a dynamic goal programming approach," *Multiple Criteria Decision Making*, vol. 13, pp. 74–87, 2018, doi: 10.22367/mcdm.2018.13.04.
- [42] D. Lestari, A. M. Abadi, A. Dhorurri, A. I. Tarigan, and E. Herlinawati, "Optimization of Nutritional-Menu Planning for Toddlers by Goal Programming Model," 2021.
- [43] Z. Alwaddood, N. Fadhlil, H. Ayob, and N. M. Noor, "A diet plan for Malaysian adolescent athletes using integer goal programming model," *Transactions on Science and Technology*, vol. 10, no. 1, 2023. [Online]. Available: <http://tost.unise.org/>
- [44] C. Sen, "Improved Multi Goal Programming Model," *Journal of Operational Research*, vol. 10, pp. 45–48, 2021.
- [45] Ministry of Health Malaysia, *Recommended nutrient intakes for Malaysia 2017*. Putrajaya, Malaysia: Ministry of Health Malaysia, 2017.