MENU PLANNING MODEL FOR MALAYSIAN BOARDING SCHOOL USING SELF-ADAPTIVE HYBRID GENETIC ALGORITHM

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by

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ABSTRAK

Masalah malnutrisi menjadi satu ancaman yang hebat terhadap tahap kesihatan masyarakat dunia hari ini. Statistik menunjukkan bilangan kanak-kanak dan remaja yang mengalami kekurangan nutrisi dan lebihan nutrisi meningkat hari demi hari. Oleh itu, proses perancangan makanan yang betul dalam kalangan ahli perancang makanan dan pengendali kantin sangat penting untuk mengelakkan timbulnya masalah kesihatan yang berkaitan dengan pemakanan pada masa hadapan. Pengiraan perancangan makanan secara tradisional tidak dapat mengambil kira makronutrien dan mikronutrien pada masa yang sama kerana melibatkan data yang kompleks dan masa pengiraan yang panjang. Dalam kajian ini, teknik Hibrid Penyesuaian Algoritma Al-Kawarizmi (SHGA) telah diperkenalkan untuk menyelesaikan masalah perancangan makanan kepada pelajar Malaysia yang menuntut di sekolah berasrama penuh yang berumur antara 13 hingga 18 tahun. Objektif model perancangan makanan penyelidik adalah untuk menggunakan sepenuhnya peruntukan yang disediakan kepada setiap pelajar, meningkatkan kepelbagaian dalam makanan harian, mengambil kira kebolehan pengendali kantin, dan memenuhi saranan pengambilan nutrisi yang ditetapkan (RNI). Kaedah pencarian setempat baru diperkenalkan dalam kajian ini, *'insertion search with delete-and-create' (ISDC)*, yang menggabungkan kaedah *'insertion search' (IS)* dan kaedah *'delete-and-create' (DC)*. Perlaksanaan *IS* sahaja tidak dapat menjamin untuk menghasilkan penyelesaian yang boleh diterima memandangkan ia hanya menerokai kawasan jiran yang kecil sahaja. Oleh itu, kaedah *ISDC* disarankan untuk mengembangkan carian kepada kawasan jiran yang lebih luas dan keputusan menunjukkan kaedah yang diperkenalkan dapat menghasilkan 100% penyelesaian yang boleh diterima dengan nilai yang baik. Selain itu, perlaksanaan kaedah penyesuaian kebarangkalian untuk mutasi ialah secara signifikan mengurangkan masa pengiraan yang diambil untuk menghasilkan keputusan yang baik dalam beberapa minit sahaja. Teknik hibrid dengan kaedah pencarian setempat dan strategi penyesuaian telah meningkatkan prestasi kaedah tradisi algoritma Al-Kawarizmi melalui skema penerokaan dan eksplotasi yang seimbang. Pada akhir kajian, satu prototaip perancangan makanan dibangunkan untuk pengendali kantin supaya dapat menyediakan makanan harian yang sihat dan bernutrisi secara lebih efisien menggunakan antaramuka pengguna yang mudah dan mesra.

ABSTRACT

Malnutrition problem is the gravest single threat to the world's public health today. Statistics have showed that the number of under-nourished and over-nourished children and adolescents is increasing day by day. Thus, proper menu planning process among menu planners or caterers is important to avoid some diet-related diseases in the future. Manual calculation of menu planning is unable to consider macronutrients and micronutrients simultaneously due to complexities of data and length of time. In this study, self-adaptive hybrid genetic algorithm (SHGA) approach has been proposed to solve the menu planning problem for Malaysian boarding school students aged 13 to 18 years old. The objectives of our menu planning model are to optimize the budget allocation for each student, to take into consideration the caterer's ability, to fulfill the standard recommended nutrient intake (RNI) and maximize the variety of daily meals. New local search was adopted in this study, the insertion search with delete-and-create (ISDC) method, which combined the insertion search (IS) and delete-and-create (DC) local search method. The implementation of IS itself could not guarantee the production of feasible solutions as it only explores a small neighborhood area. Thus, the ISDC was utilized to enhance the search towards a large neighborhood area and the results indicated that the proposed algorithm is able to produce 100% feasible solutions with the best fitness value. Besides that, implementation of self-adaptive probability for mutation has significantly minimized computational time taken to generate the good solutions in just few minutes. Hybridization technique of local search method and self-adaptive strategy have improved the performance of traditional genetic algorithm through balanced exploitation and exploration scheme. Finally, the present study has developed a menu planning prototype for caterers to provide healthy and nutritious daily meals using simple and friendly user interface.

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CHAPTER 1

INTRODUCTION

A healthy body needs sufficient nutrients from food that we eat every day. Eating more or less than what our body needs will lead to malnutrition (under-nutrition and over-nutrition). Malnutrition is defined as inadequate, excessive or imbalanced consumption of nutrients that are necessary for growth and development of the human body (Ge and Chang, 2001). The World Health Organization (WHO) cites malnutrition as the gravest single threat to the world's public health today (Silva *et al.*, 2006). Although statistic from 1969 to 1995 showed a decreasing number of undernourished people around the world, the figure surprisingly increased sharply starting 1995 until 2009 (refer to Figure 1.1).

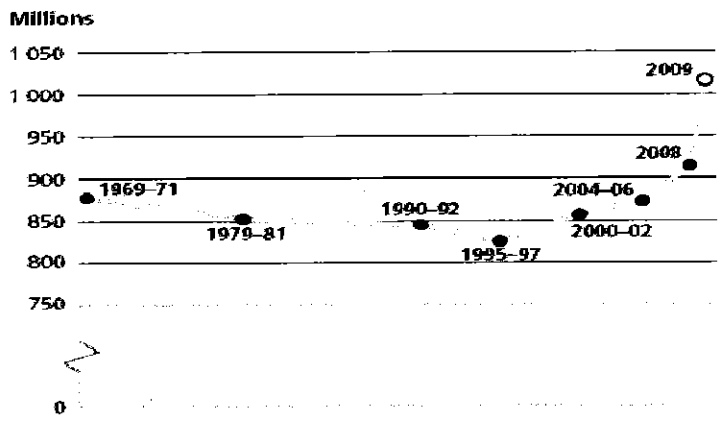

Figure 1.1: Undernourished people around the world (FAO, 2009)

Moreover, the most recent estimation for undernourishment cited by the Food and Agriculture Organization (FAO) which was released on October 14, 2009, revealed that 1.02 billion people around the world are undernourished (refer to Figure 1.2).

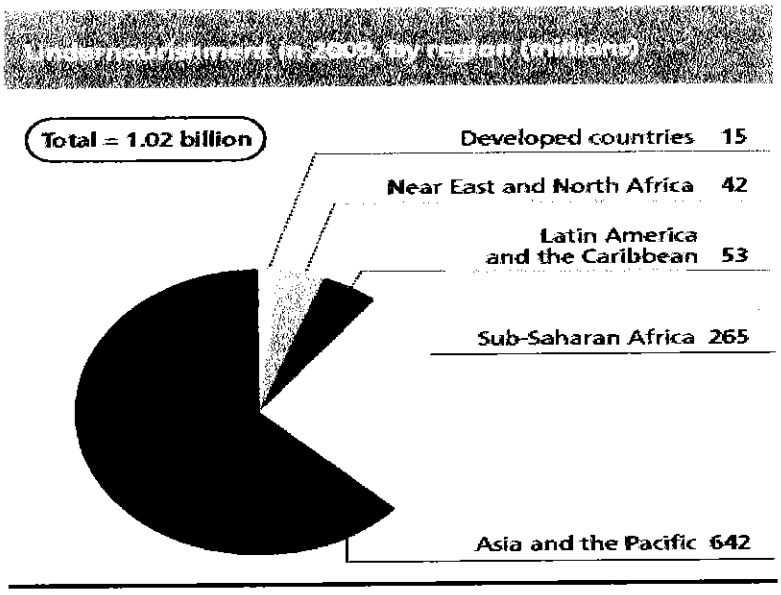

Figure 1.2: Undernourishment in 2009 (FAO, 2009)

The pie chart indicates that the fraction of undernourishment in 2009 is 15 million from Developed Countries, 42 million from Near East and North Africa, 53 million from Latin America and the Caribbean, 265 million from Sub-Saharan Africa, and the majority from Asia Pacific (642 million) respectively. The causes of undernourishment are a result of three factors, i.e. less investment on agriculture sector by government and international agencies, the current worldwide economic crisis and the significant increase of food prices over the last several years (The State of Food Insecurity in the World, 2009).

Over-nutrition is the second type of malnutrition that is due to excessive intake of essential nutrients such as energy which contributes to overweight and obesity

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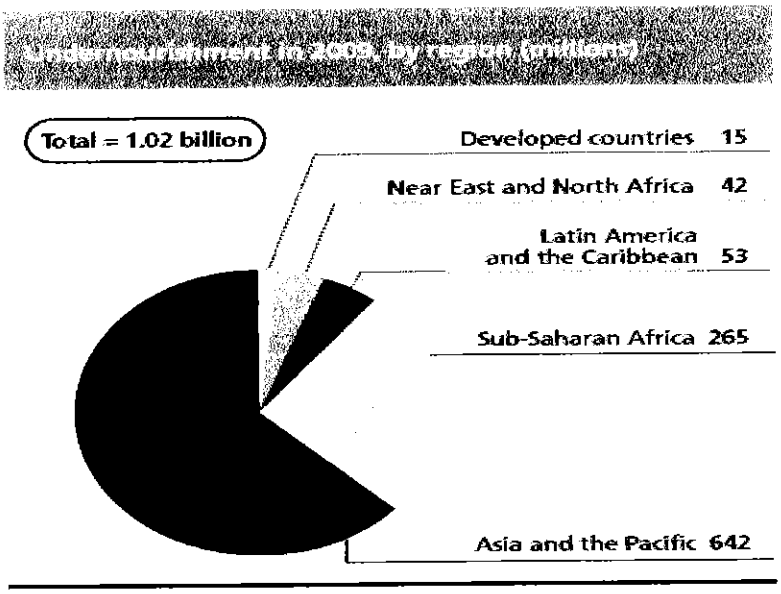

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Over-nutrition is the second type of malnutrition that is due to excessive intake of essential nutrients such as energy which contributes to overweight and obesity

problems that can cause non-communicable diseases including Type 2 diabetes, hypertension, and cardiovascular diseases (Christina, 2006). Obesity is the most serious medical problem in the world today. Intake of high-calorie foods combined with low level of daily activities is one of the factors that contribute towards excess weight and obesity problems in future.

Based on the Morbidity and Mortality Weekly Report (MMWR), on July 24, 2009, the prevalence of obesity among low-income preschool-aged children in the United States increased steadily from 12.4% in 1998 to 14.5% in 2003, and then subsequently remained essentially the same, with 14.6% prevalence in 2008 (refer Figure 1.3).

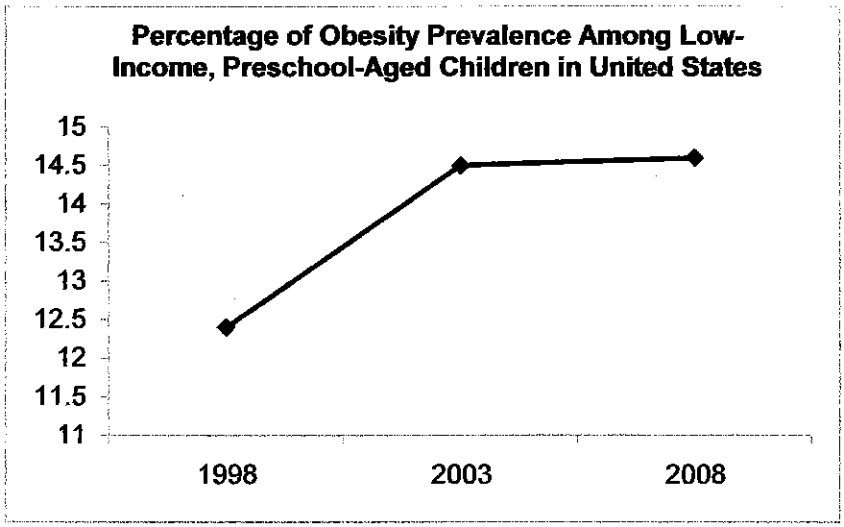

Figure 1.3: Obesity prevalence in United States (MMWR, 2009)

In Malaysia, several studies have been conducted to investigate the nutritional status of Malaysians, especially among children and adolescents. Foo *et al.* (2006) investigated the dietary intake of adolescents in rural fishing community in Tuaran, Sabah and found that the prevalence of underweight people (19.6%) is higher than overweight people (4.5%), where majority of respondents are taking nutrients less than the recommended nutrient intake (RNI) level. Another study conducted by Chee *et al.* (2008) which determined the nutritional status among female children and adolescents in welfare homes in Kuala Lumpur, also found that the percentage of underweight children and adolescents (21%) is more compared to the percentage of the overweight group (4%).

However, Lekhraj *et al.* (2007) indicated that the prevalence of overweight children among secondary school children in Klang, Selangor is still high where 11.4% were found to be at risk of excess weight and 8.2% were overweight. Prevalence of excess weight among males was found to be higher than females and majority Malay (10.7%) school children were overweight followed by Indians (7.1%) and Chinese (5.9%). Contributing factors towards being overweight and obesity problems among children and adolescents are genetics, environmental factors including the effect of excessive television viewing, fast food and soft drink consumption, home and school factors, effect of maternal smoking during pregnancy and effect of breastfeeding (Sidik & Ahmad, 2004).

In fact, children who are obese in their preschool years are more likely to be obese in adolescence and adulthood which may contribute to hypertension, type II

diabetes mellitus, dyslipidemia, left ventricular hypertrophy, nonalcoholic steatohepatitis, obstructive sleep apnea and orthopedic problems (such as slipped capital-femoral epiphysis), as well as social and psychological problems (Sorof & Daniels, 2002). Therefore, early precaution on eating habits is very important to ensure the children are given the right nutrition intake everyday for healthy generations in future. School children and adolescent groups need more attention on eating habits as they go through a period of marked physical, physiological and psychological changes.

Puberty is the process of physical development from a child to an adult. At this stage, the girls aged 10 to 11 continue to increase in growth until they are 12 and stop at the age of 15; meanwhile, the peak age for boys is 14 and will complete at 19. During this period, the rate of growth shows much individual variation with adolescents gaining about 20% of adult height and 50% of adult weight. Furthermore, most of the body organs double in size and almost half of total bones grow steadily (Drummond & Brefere, 2003).

In addition, the proportion of muscle for boys is twice that compared to the girls; meanwhile, the girls gain proportionately more fat which is stored under the skin, particularly in the area of the abdomen (Drummond & Brefere, 2003). The males experience a greater increase in bone mass then do the females. Males need more energy, protein, calcium, iron, and zinc to build muscle and develop bones faster than females, while females need increasing iron due to onset of menstruation.

At this adolescent stage, balance intake of nutrients will contribute towards proper development of human body, while imbalance content of nutrients will lead to health problems in future. The following section discusses on introduction of menu planning that have been investigated since fourth centuries.

1.1 Introduction to Menu Planning

Planning nutritious menus everyday is important to avoid insufficient nutrients that cause malnutrition. However, menu planning is not a simple process as it involves many decision criteria related to budget, variety, balance and user preferences. In addition, Drummond and Brefere (2003) listed several factors which influence food selection such as flavour, cost, nutrition, demographics, culture and religion, health, social and emotional influences, food industry and media and environmental concerns. Therefore, menu planning is one of the important areas to be investigated by nutritionists and operational researchers when attempting to prevent malnutrition. The original terminology of menu planning problem was called a diet problem. However, according to Eckstein (1970), diet problem was more suitable for animals, while menu planning problem was more relevant for humans. There are differences between both designations in simplicity of the problem, complete definition of the relevant parameters and availability of accurate, complete and reliable data (Eckstein, 1970). In our study, both terms are used interchangeably.

Studies on menu planning have been published since 1940's where the pioneer of the diet problem was George Stigler, who published the first paper in 1945. Furthermore, Stigler's diet problem was a classic example of the application of the linear programming method (Eckstein, 1970). Definition of menu planning problem is to find optimum combination of menu items which satisfy specific nutritional, structural, and variety requirements for a sequence of days (Balintfy, 1964). Then, in 1975, he redefined menu planning as the scheduling of meals associated with the person's needs for an entire day or a few days. Another definition of menu planning is given by Lancaster (1992(b)) as a menu scheduling that involve decision making process of allocating menu items to meals on a discrete time scale.

Menu planning involves simultaneous consideration of several constraints such as standard nutrient requirement for different age and gender, the preferences (likes and dislikes) of the person being planned for, the amount (volume or weight) of menu to be consumed and the variety of menus for different kinds of meals (Kovacic, 1995). In conclusion, menu planning can be defined as menu scheduling for achieving standard nutrient requirement and guidelines, structure, variety and preference of users for a specific time frame.

Diet problem was the original term used by Stigler in his study where the main objective was to find the least cost of meals for the American army using trial and error technique. His mathematical model of diet problem became the foundation of

menu planning problem for human diet today. The original mathematical model of Stigler's diet is shown below (Lancaster, 1992(b)).

$$\text{Minimize} \quad \sum_{j=1}^{J} C_j X_j$$

Subject to

$$\sum_{j=1}^{J} n_{ij} X_j \geq b_i \quad \text{for } i = 1, 2, \ldots, n$$

$$X_j \geq 0 \quad \text{for all } j$$

Where

C_j = the cost of the j-th food;

X_j = the quantity of the j-th food;

n_{ij} = the i-th nutrient content of the j-th food;

b_i = the i-th nutrient requirement.

The original objective function was to minimize the total cost of food items where the combination of these food items contains nutrients that equal the standard nutrients requirement as suggested by nutrition experts.

The Stigler's diet model was then extended and used worldwide in management science or operational research (MS/OR) technique to solve menu planning problem for humans as well as diet problem for animals such as for cattle or dairy cows (Panne & Popp, 1963; Chappell, 1974; Roush, *et al.*, 1994; Glen, 1980; Glen,

1986; Lara & Romero, 1992; Munford, 1989; Munford, 1996; Polimeno, *et al.*, 1999; Tozer & Stokes, 2001; Cadenas, *et al.*, 2004; Zhang and Roush, 2001; Mitani and Nakayama, 1997), pig (Gallenti, 1997; Jean dit Bailleul, *et al.*, 2001; Castrodeza, *et al.*, 2005; Pomar, *et al.*, 2007), aquaculture (Shaftel & Wilson, 1990) and sheep (Zioganas, 1981). Food production enterprises products that come from livestock such as cattle, sheep, pigs and others put further concerns on a feeding program as the production cost affected their organizational profit. The feeding program is known as diet probleme for animals with the objective being to determine the optimal composition of foodstuffs for animals which satisfy certain specified nutritive and other requirements at the minimum cost. The price, nutritive contents and quantities or volume of raw foodstuffs are important variables in this diet model which are not always constant but vary considerably. Sometimes, organizational policies are also taken into consideration during the development of diet model which integrate several quantitative and qualitative methods to produce the best compromised solution.

Therefore, various optimization approaches have been applied by previous researchers to solve diet problem or menu planning problem, including linear programming (Smith, 1959; Smith, 1974; Bassi, 1976; Foytik, 1981; Silberberg, 1985; Westrich *et al.*, 1998; Colavita and D'orsi, 1990; Fletcher *et al.*, 1994), integer programming (Balintfy, 1964; Leung *et al.*, 1995), multistage multiple-choice programming algorithm (Balintfy, 1975), mixed integer programming (Armstrong & Sinha, 1974), bi-criteria mathematical programming (Benson & Morin, 1987), mixed integer linear programming (Sklan & Dariel, 1993; Valdez-

Peña & Marĭnez-Alfaro, 2003) and goal programming (McCann-Rugg *et al.*, 1983).

However, combination of optimization and heuristic approaches has become the current popular approach in solving menu planning problem. For instance, trial and error exchange menu items (Noah *et al.*, 2004), steady-state genetic algorithms (Kahraman and Seven, 2005), multi-objective genetic algorithms with NSGA-II (Kaldirim and Kőse, 2006) and evolutionary algorithm (Seljak, 2009).

As many factors are involved in menu planning decision making process, work on menu planning has become more complex, complicated and time-consuming to be solved using manual calculation. In addition, evolution of science and technology in today's lifestyle as well as availability of computer technology seem to be able to enhance the area of menu planning by developing computerized assisted menu planning where the pioneer of this approach was Balintfy (1964). Detailed discussion on the evolution of menu planning issues is stated in the review of literature chapter.

Our study aims to focus on menu planning problem for Malaysian boarding school students using the proposed hybrid optimization and heuristic approach. However, review of current techniques used in planning menu among Malaysian nutritionists and dietitians were held through a survey and interview session in order to gain more data and information which can benefit our study.

1.2 Background and Problem Statement

Caterers are hired to provide food for the students in boarding schools and are responsible to provide six categories of meals per day consisting of breakfast, morning snack, lunch, evening snack, dinner and supper. Every student is allocated a certain budget by the government for daily meals and this budget is later transferred to the responsible caterers for buying, cooking and serving suitable menus for the students. The total budget allocated per student depends on the school's location or area. For example, the budget for a boarding school in a rural area is much lower compared to a boarding school in an urban area because the food resources in the urban area are more expensive and difficult to get. Therefore, total budget for caterers is not the same for all boarding schools.

The survey done in one of the boarding schools reveals that the nutritionist from the Ministry of Education is responsible for planning menus for students for a duration of one month and later on, the suggested plan is delivered to all the boarding schools around Malaysia. According to interview session with the dietitians and nutritionists in the National University Hospital of Malaysia and Kangar Hospital of Perlis on 15 March, 2006 and 4 April, 2008 respectively, the current approach to menu planning used by them is manual calculation approach using Excel spreadsheet. Using Matchbox method (Annual Obesity Report, 2004), they plan the menu by exchanging the menu items according to Exchange List and seven types of food groups are considered for four categories of meals which are breakfast, lunch, snack and dinner per day.

In exchanging the menu items, they applied trial and error approach to meet the nutritional guidelines and personal user requirement which produced several different results from other dietitians or nutritionists since they have various opinions and different intuition. They were only capable of considering four types of macronutrients which are energy, carbohydrates, protein and fat as involving other micronutrients will cause complexity and difficulty in finding the best solution. Therefore, they made assumption that other micronutrients will be achieved automatically if the macronutrients are fulfilled. This happened due to human limitations to solve the complex menu planning problem that involves thousands of menu items and several hard and soft constraints. Also, they took half an hour or more to attain the most appropriate solution for healthy meals.

Administrators in each boarding school are responsible to supervise the meals provided by the caterer at their school to ensure that the meals are provided according to the plan. However, the caterer is also given options to choose the appropriate menus based on their cooking skill ability, raw food availability, human resource capability, cost of food items and total budget given. The objective of the government and the school authority is to utilize the entire budget given by providing nutritious meals as suggested by food guide pyramid that can fulfill the RNI requirements in order to ensure all students are always getting balanced and nutritious diet. On the other hand, maximizing profit is usually the main target of any business entity. As such, the caterer who is responsible for providing the menus would aim to minimize the total cost. In doing so, there is the possibility that the cost factor will prevail over nutrients.

Furthermore, in some other situations, students are fed with limited variation of menu sets. As such, planning for the proper menu to satisfy the three stakeholders (the government, the caterer and the students) can be very complicated and deserves special attention. Therefore, to overcome the problems faced by caterers, a new menu planning model has to be developed which will be able to satisfy multiple objectives and overcome several constraints by using remarkable approaches such as optimization and heuristic approach in order to produce better solution. Instead of using manual calculation, menu planning system offers more effective way in planning daily meals and able to decrease the time to generate the good solution. The motivation of this study is to help caterers in menu planning problem by developing menu planning prototype which is able to produce healthy daily meals for students.

In operational management area, menu planning can be categorized as NP-hard problem (Seljak, 2009). It involves thousands of variables menu items and hundreds of constraints which are not reliable for optimization approach. Moreover, it has caused computational problems and is costly to search for optimal solution from huge solution space. Searching for optimal set of menu items is not the main concern for menu planning as long as the solution fulfills all constraints that meet RNI requirement and is within the budget. Instead of using optimization approach, some researchers applied heuristic approach such as genetic algorithms (GA) to solve menu planning problem (Kahraman and Seven, 2005; Kaldirim and Kőse, 2006; Seljak, 2009). Although GA is capable to produce feasible solution, the original GA cannot guarantee every run to produce feasible solutions as many

constraints have to be considered (El-Mihoub et al., 2006). Therefore, hybridization genetic algorithms with other methods can hopefully assist the search towards a feasible solution.

The drawback of existing hybrid genetic algorithms approach developed by Kahraman and Seven (2005), Kaldirim and Kőse (2006) and Seljak (2009) is the infeasible individual is allowed to enter the next generation after crossover and mutation operations. They only apply local search method in initialization step which may lead to high possibility of getting infeasible solution for small number of population size and population generation. Therefore, more restrictions have to be made to ensure only feasible solution is considered for the new generation in order to decrease the number of infeasible solution in the population. Our study aims to fill the gap to improve the performance of previous hybrid genetic algorithm approach.

1.3 Research Objectives

The main aim of this study is to develop a new menu planning model for daily menu generation of Malaysian boarding schools. More specific objectives are to:

1. Identify the common constraints to be considered in the menu planning model which are able to:
    i. optimize the allocated budget,
    ii. take into consideration the caterers' ability based on their cooking capability,

iii. fulfill all standard RNI requirements, and

iv. maximize variety with no repeated menu items in daily meal.

2. Propose a new algorithm by integrating genetic algorithms with local search approaches that can produce feasible solutions.
3. Formulate a new algorithm to reduce the processing time of generating the best solution.
4. Validate the proposed menu planning model by developing a new menu planning prototype which allow user to select preferred menu items via interface.

1.4 Scope of the Study

The focus group of this study is adolescents studying at Malaysian boarding schools, aged between 13 to 18 years. The data for Malaysian menu items and its nutritional value are taken from the book of Nutrient Composition of Malaysian Foods, compiled by Tee *et al.* (2002). Eleven nutrients were considered including energy, protein, fat, carbohydrates, vitamin B1, vitamin B2, niacin, calcium, vitamin C, vitamin A and iron. Each of these nutrients is considered based on the lower bound and upper bound requirements respectively, with respect to the student age group requirement.

1.5 Significance of the Study

There are several advantages of our study in the operational research area especially in genetic algorithms theory, as well as for practical purposes. Firstly,

this study brings a new foundation for Malaysia in solving menu planning problem using scientific approach, i.e. hybrid genetic algorithms. This proposed approach is able to consider various Malaysian menu items and fulfill several constraints related to budget, nutrition requirement, variety of menu items and the caterer's ability. Furthermore, this study can be enhanced to other applications such as for children (1-9 years old), adults, pregnant women, athletes and old folks by doing minor adjustments in related data.

Secondly, our study is meant to assist the caterer as well as school authority in decision making process to provide high quality meals for students in just a few minutes via user interface of menu planning prototype. Even without deep knowledge in operational research methods and nutrition field, they will be able to plan healthy meals using the menu planning prototype efficiently and easily.

Thirdly, this study can be a guideline for nutritionists to explore a new approach of menu planning compared to the traditional method. In addition, this new approach is more accurate which considered not only macronutrients, but micronutrients as well. Moreover, it may help nutritionists to lessen the time taken to produce healthy meals and at the same time, achieve the needs and preferences of users.

Finally, in the academic area, this study enhances the application of hybrid genetic algorithms theory with local search and self-adaptive probability for mutation to solve a real world complex problem in the area of menu planning. This new

application may hopefully contribute benefits to human life using knowledge of heuristic and optimization which can lead to very bright opportunity for operational management scientists in future.

1.6 Definition Related to Menu Planning

Before going further, definition of the basic concepts of menu planning is important to gain clear understanding on what is going to be discussed in the next topics. The basic concepts involved in this study are nutrition, nutrients, macronutrients, micronutrients, essential nutrients, food guide pyramid, recommended nutrient intakes, tolerable upper intake level and characteristics of nutritious diet.

1.6.1 Nutrition

Nutrition is a science that studies nutrients and other substances in foods and in the body and how these nutrients relate to health and diseases. Nutrition also explores the reasons for choosing particular foods and the type of diets (Drummond & Brefere, 2003).

1.6.2 Nutrients

Nutrients are nourished substances in foods that provide energy and promote the growth and maintenance of body (Drummond & Brefere, 2003). In addition,

nutrients play an important role in assisting the regular processes of the body such as digestion and heart rate to support optimum health. There are many essential nutrients for our body that can be divided into macronutrients and micronutrients.

1.6.3 Macronutrients

Macronutrients are the nutrients needed by the body in large amounts which are carbohydrates, protein, and lipid. Carbohydrate is a large class of nutrients including sugar, starch and fibers that function as the body's primary source of energy for about 40% – 80% (RNI, 2005; Drummond & Brefere, 2003). Energy from carbohydrate is important for the brain which is the only carbohydrate-dependent organ in the body. Moreover, unlike fat and protein, an excessive consumption of dietary carbohydrate is not associated with adverse health effects and reduces the likelihood of developing obesity (RNI, 2005).

Protein is a major structural part of the body's cell that is made of nitrogen-containing amino acids assembled in chains (Drummond & Brefere, 2003). It is essential for the body's growth, maintenance of tissues and defends the body from diseases. Protein is particularly rich in animal resources such as beef, chicken, fish, and milk. Lipid is a group of fatty substances, including triglycerides and cholesterol that are soluble in fat, not water, and provide a rich source of energy and structures of cell (Drummond & Brefere, 2003). Although lipid is a major determinant of energy density of diets, consuming fat excessively will contribute to obesity problem.

1.6.4 Micronutrients

Micronutrients are the nutrients needed by the body in small amounts, including vitamins and minerals. Vitamins are non-caloric, organic nutrients found in a wide variety of foods that are essential in small quantities to regulate the body processes, maintain the body and allow growth and reproduction. On the other hand, minerals are inorganic chemical substances that have the same function as vitamins (Drummond & Brefere, 2003). The examples of vitamins are Thiamin (Vitamin B_1), Riboflavin (Vitamin B_2), Niacin (Vitamin B_3), Folate, Vitamin C, Vitamin A, Vitamin D, Vitamin E, while Calcium, Iron, Iodine, Zinc, and Selenium are examples of minerals (RNI, 2005).

1.6.5 Essential Nutrients

Essential nutrients are nutrients that either cannot be made in the body or cannot be made in the quantities needed by the body, so they only could be obtained from foods that individuals eat (Drummond & Brefere, 2003). These include carbohydrates, vitamins, minerals, water, some lipids and some part of protein.

1.6.6 Food Guide Pyramid

Food guide pyramid is developed by the U.S. Department of Agriculture (USDA) to assist healthy Americans follow the Dietary Guidelines for Americans (Drummond & Brefere, 2003; Nutrition Society of Malaysia, 2000). The objectives of food guide pyramids are to promote overall health for Americans of seven years

of age and older, incorporating the most current research, focus on the total diet, and as a tool to be used practically. They are divided into four levels, which are (Refer Figure 1.4):

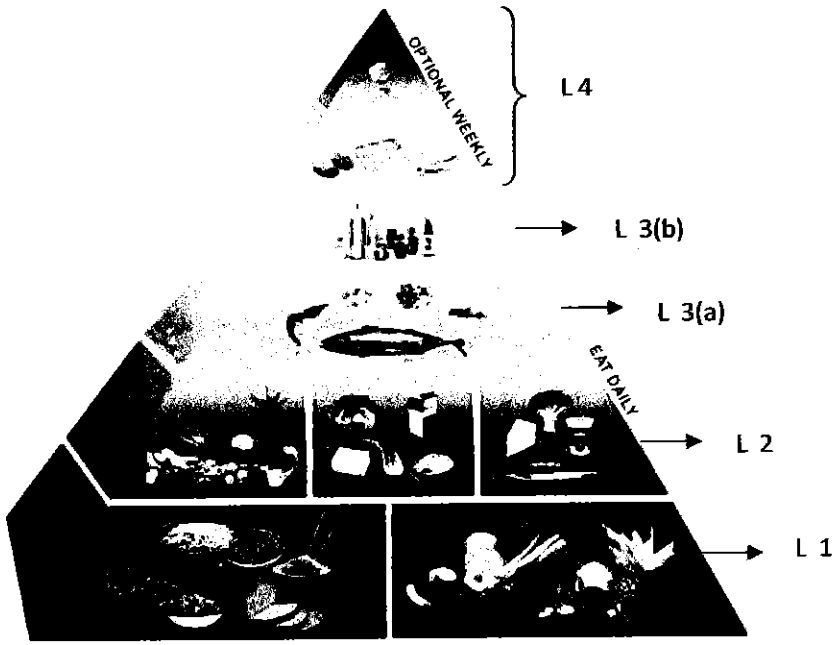

Figure 1.4: Food Guide Pyramid (RNI, 2005)

i. Level 1: Rice, noodles, bread, other cereals and cereal products and tubers (8 to 12 servings per day)

ii. Level 2: Fruits and vegetables (3 to 5 servings per day)

iii. Level 3(a): Fish, poultry, meat and legumes (2 to 3 servings per day)

iv. Level 3(b): Milk and dairy products (excluding condensed milk, butter, and cream) (1 to 2 servings per day)

v. Level 4: Fats, oil, sugar and salt (small amount)

People are encouraged to eat more carbohydrates which is the main source of energy and a variety of fruits and vegetables that can protect against many chronic diseases. On the other hand, people should avoid taking foods which contain high fat, added sugar and which are low in nutrient density such as butter, margarine, oils, sugars, jam and soft drinks. Balanced intake of various foods and eating variety of foods are important to contribute towards a healthy body.

1.6.7 Recommended Nutrient Intakes

Drummond and Brefere (2003) define recommended daily allowance (RDA) as the dietary intake value that is sufficient to meet the nutrient requirement of 97 to 98 percent of all healthy individuals in a group. Besides that, in a handbook of Malaysian RNI 2005, the definition of RDA is described as the level of intake of essential nutrients that, on the basis of scientific knowledge, are judged by the Food and Nutrition Board, to be adequate to meet the known nutrients needs of practically healthy persons. Various terms of RDA are used such as recommended daily allowances, recommended daily amounts and recommended nutrient intakes (RNI). In our study, RNI is adopted to refer to dietary recommendations.

1.6.8 Tolerable Upper Intake Level

Upper intake level (UL) is a maximum intake from foods that will not pose risk of adverse health effects from excess in almost all (97.5%) apparently healthy individuals in an age and sex-specific population group (RNI, 2005). Total intakes

of nutrients which fall within the range of RNI and UL are considered sufficient to prevent deficiency while avoiding toxicity (Refer Figure 1.5).

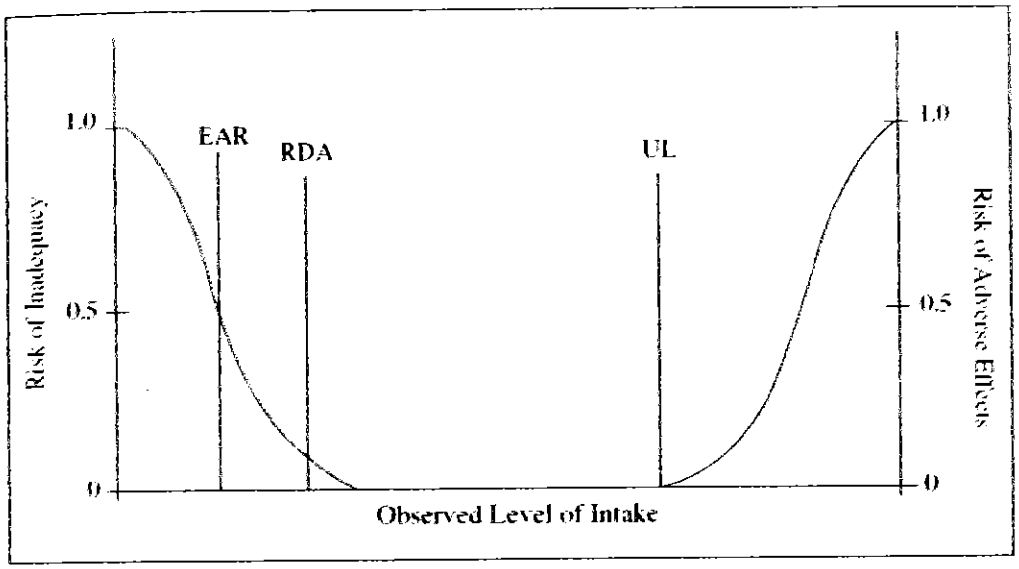

Figure 1.5: Conceptual framework for IOM/FNB's recommended nutrient intake (RNI, 2005)

A requirement is an intake level, which will meet specified criteria of adequacy, preventing risk of deficit or excess. These criteria include a gradient of biological effects related to the nutrient intake. The estimated average requirement (EAR) is the median intake value that is estimated to meet the requirement, as defined by specified indicator of adequacy, in half of the individuals in a life-stage or gender group. The EAR is used to calculate the RDA (RNI, 2005).

1.6.9 Characteristics of Nutritious Diet

There are four characteristics known as nutritious diet which are adequate, balanced, moderate and varied (Drummond & Brefere, 2003; Nutrition Society of Malaysia, 2000). Adequate diet will provide enough energy, essential nutrients and fiber to keep a person healthy, whereas a moderate diet will avoid excessive amounts of energy and other nutrients. For example, if individuals eat too much fried food and too much soda that contains a lot of sugar, it will contribute to obesity because of excessive energy.

Therefore, people should eat a balanced diet by choosing the right proportion of energy, essential nutrients and fiber as suggested by standard requirements. In addition, eating varied diet means choosing a wide selection of different food groups which will produce necessary nutrients for us. In fact, different food provide different combination of energy and essential nutrients. Variety can be achieved by eating a combination of food groups contained in the Food Guide Pyramid.

1.7 Organization of Thesis

This thesis is organized as follows. Chapter Two discusses reviews of past literature that relate to the area of menu planning for human diet using different solution approaches and application of the theory of hybrid genetic algorithms in various areas. Chapter Three presents the methodologies involved in this research. Next, the description of model development and the proposed technique in solving

menu planning problem are presented in Chapter Four. Chapter Five focuses on extensive description on the experiment, analysis and result of the proposed model, while Chapter Six explains the extended menu planning model with variety constraints. This thesis ends with the discussion on contributions of this research and recommendations for future work in Chapter Seven.

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