Mobile Application: An Approach with the Analytical Hierarchy Process (AHP) for the Allocation and Generation of Dietary Plans

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Abstract. **Obesity prevalence rates rise every year around the globe. This has become an alarming issue, due to the distress caused by the high probability of developing obesity in childhood which continues into adulthood, creating great health problems and even mortality. As a result, emerging technologies such as mobile applications have had a direct impact on the world of health, these rely on various specialized algorithms. This study seeks to propose an approach based on the Analytical Hierarchy Process (AHP), to assign and generate dietetic plans which will be used by nutritionists and patients. This approach consists of five phases: (1) anthropometric data definition, (2) macronutrients selection, (3) dietary meals dataset definition, (4) AHP definition (in order to obtain the best macronutrient and dietary meal) and (5) mobile application design. Two different experiments were conducted in a private medical entity, involving eight nutritionists and eight patients, who considered the following metrics: the "creation time of dietetic plans", the "number of monthly revisions", the "precision level" and the "satisfaction levels". The results showed that mobile application users achieved significantly better outcomes in the assignation and generation of dietetic plans than those who used the traditional method.**

I. INTRODUCTION

A study published by the World Health Organization [1] determined that obesity has tripled itself since 1975, and during 2016 there were more than 1900 million adults and 340 million children who were overweight/obese, clearly all of that is of great concern, knowing that these are potential factors which could lead to the mortality of another disease. This is a worrying issue since obesity at an early age tends to prevail until adulthood and increases morbidity and mortality chances. Furthermore, obesity is associated with a range of medical complications such as: cardiovascular diseases, hypogonadism, orthopedic problems, various fatty liver related diseases, among others. Therefore, food intake is vital for a person's health and prevents all the problems associated with obesity/overweight.

Moreover, [2] points out that an unbalanced and unhealthy diet could lead to obesity prevalence. In addition, these poor habits imply greater cardiovascular risk and higher mortality. Thus, it is vitally important to adopt a healthy diet, to ensure better results and prevent future diseases.

Furthermore, an epidemiological study conducted by the Ministerio de Salud (MINSA) [3], in which 199 countries were analyzed in order to estimate obesity and overweight prevalence worldwide, concluded that between 1980 and 2008, obesity prevalence rates raised from 6,4% to 12,0% while overweight prevalence increased from 24,6% to 34,4% during the same period. During the COVID-19 pandemic, healthcare establishments have been affected by the lack of knowledge of modern technologies. As a result, all health areas have been negatively impacted, the nutrition area being one of them. Because of this, the MINSA has produced a new strategy called "*Bicentenary Digital Agenda*" which seeks to contribute to the quality improvement of health services through digital products [4]. At the same time, the application of digital technologies in the health sector must be guided by specialized doctors [5].

To solve this issue, numerous studies which provide different models, like "descriptive statistics" [6], [7], [8], have surged. This model is focused on the search of specific patterns among a number of users previously interviewed and the estimation of probabilities to obtain a rough average. Likewise, the multivariate logistic model [8], [9], [10], is used to recommend suitable dietetic plans, which main goal is to obtain a dependent-independent variable estimation, this will lead to corroborate the causes and predict these said variables values approximately. However, none of the studies focus on the AHP model for the assignation, monitoring, and generation of dietary plans, which could be used to enhance these processes.

For this reason, this study seeks to propose an approach based on the Analytical Hierarchy Process (AHP), to assign and generate dietetic plans. This approach consists of five phases: (1) anthropometric data definition, (2) selection of macronutrients, (3) dataset definition of dietary dishes, (4) AHP algorithm definition and (5) design of the mobile application. The proposal focuses on 2 key users: patients with obesity and overweight, and nutritionists. The purpose of this mobile application is to be a used as a tool to support the people involved in the monitoring and generation of dietary plans, considering the most appropriate macronutrients.

This article presents the following structure. First, we have various related projects in section 2. Next, the details of the AHP approach for the assignation and generation of dietetic plans can be found in section 3. The fourth section describes the validation of the proposed approach and its execution. As a matter of fact, the results obtained from this validation are portrayed among section 5. Lastly, conclusions and future projects are outlined in section 6.

II. RELATED WORKS

The literature review was based on Wong et al. project. [11], in which the following phases were applied: (1) planification, (2) development, (3) results and analysis. In order to complete the planification phase, 4 key questions were raised. The first question identifies the main factors that cause obesity in teenagers, "*Which factors cause obesity among teenagers?*" (RQ1). The second question validates the proposed technologies in different studies, "*Which technologies have been proposed to slow down the obesity epidemic?*" (RQ2). The third question's main focus is the type of techniques used by different systems, "*Which techniques have been applied for the assignation of dietetic plans for obese people?*" (RQ3). The last question proposes an investigation of the numerous results obtained between different study cases, "*In whom have diet plan technologies been applied?*" (RQ4).

Also, prior to the development phase, inclusion criteria have been selected conducted to filter the most relevant articles related to the proposed topic. Firstly, keyword combinations were defined, in order to find articles related to the selected subject: obesity, weight excess, health applications, mhealth application, randomized controlled trial and multi-criteria decision-making model. Second, it was defined that the selected articles had to be found in the Scopus or Web of Science database. Third, the selected articles had to be published after 2019 and belong to the first, second or third quartile. Finally, articles pertaining to "Computer Science" category were prioritized.

For the development phase, previously mentioned criteria were used for the search of relevant articles. Likewise, a preliminary review of each article found was carried out in order to filter out the most important articles in terms of content. These articles were analyzed according to a taxonomy composed of 4 categories. In Table I, the selected articles are showed, classified in categories, according to the proposed taxonomy.

A. Factors

Numerous factors which contribute to obesity prevalence have been found (see Table II). The most relevant factors are the non-healthy meals factor [12], [13], [14] and sedentarism [6], [18], [19], which represent 34,6% and 19,3%, respectively. In a study written by Jongjit Rittirong et al [34], which suggests that socioeconomical background are related to more sedentary occupations [20], [17], being more likely to suffer from overweight or obesity. Another study points out that it is difficult to access healthy food [8], [29], since these foods are often out of reach for people from low socioeconomic levels [28], and consequently, they tend to consume unhealthy foods [7], [15]. Finally, inefficient applications [21], stress [24], [25] and genetics [19] were identified as factors too.

B. Technologies

Several technologies for food monitoring have been found (see Table III). The technologies with the highest use were applications [12], [6], [8] and systems [14], [7], [25], representing 42.82% and 34.78% of the total analyzed, respectively. Similarly, technologies such as web platforms [19], [27] and devices [33], [17] were identified. Some of them can be used in conjunction with sensors that will help food control, for example, motion sensors, monitoring sensors, metabolic sensors, among others. In a paper by Arsalan Shahid [30], it is noted that sensors are intended to collect data, which can be processed in the four technologies mentioned.

C. Technics

Several different techniques (see Table IV) used for food management systems have been found. The most used techniques in the articles are the qualitative descriptive content analysis model [6],[8], descriptive statistics model [7],[8], multivariate logistic regression models [9],[10] and multiple linear regression model [7],[9], each of these techniques represent 15.38% of the total. Likewise, it was identified that there are currently few articles that use the multi-criteria decision model [14], despite its high capacity for personalization and identification of user preferences regarding dietary plans. Of the previously mentioned techniques it can be pointed out that the multivariate logistic regression model, the multicriteria decision model and the multiple linear regression model seek to interpret the possible future decisions of users through parameters, past data, or samples. Lastly, less used techniques were identified such as: thematic analysis model [12], theoretical model of change theory [8], mixed linear modeling [7] and Demographic Collaborative filtering [34].

D. *Age Group*

Many age groups (see Table V) which are used for samples in various articles have been found. Most studied age groups were old age [6], [8], [7] and adulthood [12], [6], [8], which represent a 61,535 and 53,84% of the total studied articles, respectively. For this, it can be deduced that there is a wide range of studies on obesity applied in adults. In the same way, other age groups were identified such as, adolescence and youth, which were less present among the studied articles. In a paper by Hu et al [8] it is discussed that age and weight loss are highly related, since people in adolescence [24], [26] and young adulthood [24], [26] tend to unbalance their dietary treatment control, consequently, they do not lose weight.

TABLE I. TAXONOMY OF ARTICLE DISTRIBUTION BY CATEGORY

Taxonomy	Sources
Factors (RQ1)	[12], [13], [14], [7], [15], [10], [16], [17], [6], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [8], [29].
Technologies (RQ2)	[12], [6], [8], [21], [24], [18], [20], [15], [22], [23], [14],[7], [25], [13], [30], [31], [32],[19], [27], [33], [17].
Techniques (RQ3)	[12],[6], [7], [10],[8],[14], [9], [28], [34]
Age Group (RQ4)	[24], [26], [8], [20], [15], [13], [7], [12], [8], [9], [18], [19], [6], [27]

TABLE II. OBESITY FACTORS

Factors	Source
Non-healthy meals	[12], [13], [14], [7], [15], [10], [16], [17]
Sedentarism	[6], [18], [19], [20], [17]
Inefficient applications for dietary self-monitoring	[21], [22], [23]
Stress	[24], [25], [28]
Socioeconomical factors	[26], [27], [28]
Genetic factors	[19]
Difficult access to healthy meals	[8], [29]

TABLE III. OBESITY-REDUCING TECHNOLOGIES IDENTIFIED IN THE ARTICLES STUDIED

Technologies	Source
Applications	[12], [6], [8], [21], [24], [18], [20], [15], [22], [23], [30]
Systems	[14], [7], [25], [13], [30], [31], [32]
Web platforms	[19], [27], [30]
Dispositive	[33], [17], [30]

TABLE IV. TECHNIQUES APPLIED IN TECHNOLOGICAL SOLUTIONS TO THE PROBLEM OF OBESITY

Techniques	Source
Thematic analysis model	[12]
Qualitative descriptive content analysis model	[6], [8], [28]
Descriptive statistics model	[6], [7], [8]
Multivariate logistic regression models	[8], [9], [10]
Theoretical theory of change model	[8]
Multi-criteria decision model	[14]
Linear mixed modeling	[7]
Multiple linear regression models	[7], [9], [28]
Collaborative Demographic Filtering	[34]

TABLE V. AGE GROUP - POBLATION OF STUDY

Age Group	Age range	Source
Adolescence	12-18 years old	[24], [26], [8], [20], [15]
Youth	14-26 years old	[24], [26], [13], [7], [9]
Adulthood	27-59 years old	[12], [6], [8], [7], [9], [18], [19]
Old age	60 or older	[6], [8], [7], [9], [27], [18]

III. PROPOSED APPROACH

This section presents the approach for the management of a dietary food plan based on the multi-criteria decision model (AHP). The approach focuses on 2 users: patients (patients suffering from obesity and overweight) and nutritionists. The approach consists of five phases: (1) anthropometric data definition, (2) macronutrients selection, (3) dietary meals dataset definition, (4) AHP algorithm definition and (5) mobile application design for the assignation and generation of dietary plans for people who suffer from obesity based on the explained approach (see Fig. 1).

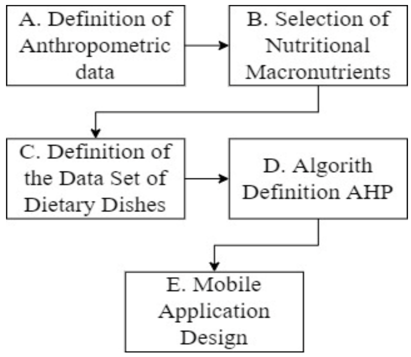

Fig. 1. Representation of the proposed approach

A. Anthropometric data definition

The chosen anthropometric data are height, weight and body perimeters. According to [35], these data will be used to evaluate the size, proportions and composition of the human body, in order to predict the health performance of the person. Similarly, to evaluate the nutritional status, anthropometric indicators (weight and height) should be analyzed together, which is why periodic monitoring is essential. Finally, in [36] the reason for the analysis of these data is the calculation of the body mass index (BMI), according to the technical guide for anthropometric nutritional assessment of MINSA, this is generated from weight and height measurements, which are adjusted according to age and sex

B. Macronutrients selection

Foods are composed of 3 essential macronutrients (M macronutrients) proteins, carbohydrates and fats (see Table VI). The latter are the evaluation criteria for the first composition matrix.

TABLE VI. EVALUATION MACRONUTRIENTS AND THEIR IMPORTANCE

Macronutrients	Description
Proteins	In [37], proteins are defined as molecules consisting of chains of amino acids linked together by peptide bonds. They constitute about half of the total mass of body tissue, which means that all cells in the body contain proteins that form muscles, skin, organs, glands and some body fluids.
Carbohydrates	In [37] carbohydrates are better known as sugars, these are biomolecules formed by three basic elements: carbon, hydrogen and oxygen. Their most important function is to help collect and store the energy needed by the body.
Fats	In [37] fats also known as lipids are compounds that are essential for health. They provide energy and help the body absorb vitamins. But certain types of fat can play a role in future heart diseases and could even be one of the causes of a stroke. In addition, fat is rich in calories.

C. Dietary meals dataset definition

The development of the dataset is composed of the name of the dish, fats, carbohydrates, proteins, ingredients, mealtime and the region where said dish is located. Likewise, the historical data of the foods registered in the Peruvian table of food composition, shown in [38], were taken as an initial basis. Therefore, each dish registered in this list corresponds to 100 grams of food. Finally, it should be noted that, at the end of the development of the dataset, this table will be shown to the nutritionist, and they will be able to update if necessary, so the plan is more compatible with the patient.

D. AHP Algorithm Definition

The multicriteria decision model is used to assist people in making decisions according to their preferences [39]. According to [40] this model allows users to reach the best option for them, when many evaluation criteria are present. That is, if the user didn't choose the alternative, other options are given, until the best choice is found in the decision making. Moreover, in [41], the difference with the multicriteria model is that in AHP there is a more flexible choice of preferences, using evaluation criteria and automatic generation of options.

1. Hierarchization of the problem: For the conceptualization of the AHP model in a dietary plan generation system, three levels are being considered. These levels consist of objective (level 0), criteria (level 1) and alternatives (level 2), as shown in Fig. 2. Furthermore, the objective of the study is represented by the ¨dietary plate recommendation¨, the criteria by the ¨macronutrients¨ and the alternatives by the various ¨plates¨.

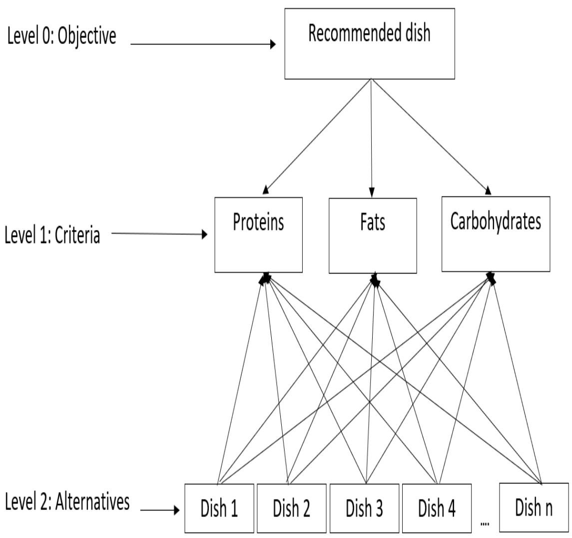

Fig. 2. AHP - Recommended Dish

It is necessary to establish that the objective of the AHP can be found at level 0, in other words, to obtain the best food dish for the dietary plan, based on the information given regarding the necessary macronutrients. Likewise, level 1 refers to the definition of the necessary criteria for each recommended dish. Finally, level 2 refers to the generation of alternatives of selected food dishes that are part of the dataset. Also, the AHP model in the definition of the calculation presents two matrices, which are the criteria and the alternatives. First of all, the criteria matrix presupposes an evaluation or assessment of criteria to define their importance at a numerical level. Lastly, the matrix of alternatives presupposes an evaluation of which meal is better than the other, following an evaluation of criteria.

2. Value judgment: To develop the approach, value judgment is applied to measure the level of acceptability of each criterion and alternative. In [39] a range from 1 to 9 is proposed to represent the weight level of each criterion or alternative. This range is applied to a pairwise comparison matrix at each hierarchical level (level 1 and level 2). It should be noted that a comparison matrix is made for each alternative with each criterion.

The comparison matrix is denoted by the equation Eq. (1).

$$[C_{ij}] \tag{1}$$

Where, $C_{ij} = 1; \quad si \quad i = j$

And if, $[C_{ij}]$ = value, then the cell's value is $a_{ji} = 1/value$. In addition, weightings are performed. (V_x) and summations (S_x), as shown in Table VII.

TABLE VII. ESTIMATED WEIGHTS FOR THE ALTERNATIVES

Criterion	C1	C2	C3	Vector
C1	$C_{11} = 1$	C_{12}	C_{13}	V1
C2	$C_{21} = 1/C_{12}$	$C_{22} = 1$	C_{23}	V2
C3	$C_{31} = 1/C_{31}$	$C_{32} = 1/C_{23}$	$C_{33} = 1$	V3
Sum	S_1	S_2	S_3	1

For the calculation of the level of acceptance of the criteria and alternatives, the Consistency Index of the matrix of criteria and alternatives (CI), Random Consistency Index of criteria and alternatives (RI), Consistency Ratio (CR) are considered.

It is determined by calculating the vector of each matrix and adding its values (n_{max}) and the number of criteria or alternatives(n). Furthermore, the equations used are as following:

$$C.I. = \frac{n_{max} - n}{n - 1} \tag{2}$$

$$R.I. = 1{,}98 \times \frac{n - 2}{n} \tag{3}$$

$$C.R. = \frac{C.I.}{R.I.} \quad ; \; Si\; C.R < 10\% \; (Aceptable) \tag{4}$$

If this result is below 10%, then the weights of the criteria and alternatives are acceptable.

3. Calculation of weights: For the implementation of the AHP model to a dietary plan generation system, the intervention of a nutrition specialist was considered to provide a value judgment on the necessary weights in the criteria matrix (macronutrients). Because of this, the nutritionist applied the AHP calculation methodology, following the next steps: (a) training on the AHP tool in Excel, (b) scoring of the weights according to Saaty [42] for the criteria, and (c) calculation of the acceptability of the nutritionist's score.

Therefore, a rank estimation validated by the nutritionist was used to calculate the weights of the alternatives. First, the levels of importance in relation to the dishes were defined in Table VIII, according to the Saaty scale [42].

TABLE VIII. IMPORTANCE LEVELS ACCORDING TO SAATY

Scale	Explanation
1	Plate A and B are of equal importance
3	Dish A is slightly more important than dish B
5	Dish A is more important than dish B
7	Dish A is much more important than dish B
9	Plate A is extremely more important than plate B

In Table IX the weights defined by a nutritionist (carbohydrates and proteins) are shown as well. As can be noted in this table, proteins are 3 times more important than fats and 5 times more important than carbohydrates. Additionally, fats are 3 times more important than carbohydrates. To contrast the level of acceptance of the specialist's criterion, the CR was calculated according to Eq. (4), in which it was obtained that the CR is 4.2%, in definition it is at an acceptable level.

TABLE IX. CALCULATION OF WEIGHTS BY THE NUTRITIONIST

Criterion	Fats	Carbohydrates	Proteins
Fats	1,00	3,00	0,33
Carbohydrates	0,33	1,00	0,20
Proteins	3,00	5,00	1,00

Consequently, the appropriate ranges in relation to the Saaty scale [42] were defined by a nutritionist (see Table X). This range reflects the difference of approximations to the ideal that two dishes have for each macronutrient, measured in grams.

TABLE X. RANGE OF DIFFERENCE OF APPROXIMATIONS ACCORDING TO THE NUTRITIONIST

Min. (grams)	Max. (grams)	Saaty Scale
0	3	3
3	5	5
5	7	7
7	To more	9

Then, the two definitions (Tables IX and X) were used to calculate the weights in a comparison matrix. The following steps were used: (1) the 3 dishes were classified, prioritizing the one closest to the ideal in macronutrient M and (2) the approximations, in grams, of each dish to the ideal (I) were calculated (see Table XI).

Then, the differences of plate-to-plate approximations (alternatives) are calculated and scored taking into account the ranges in Table X, obtaining a comparison matrix of alternatives.

E. Mobile Application Design

The proposed approach will be used to manage a nutritional plan. This approach focuses on 2 users: patients who are suffering from obesity and overweight, and nutritionists. The design phases of the mobile application will be described in the following paragraph. First, the patient registers his data (personal and anthropometric data) in the application, which will be stored in a database. In the next phase, the data is evaluated in the algorithm to assign a correct body mass index according to the patient's anthropometric data. Next, the personalized dietetic plan will be created and shown to the nutritionist, who will be able to modify it according to their own criteria. In the final phase, monitoring will be daily, the user will have to mark the compliance with the diet per day to send this information to the nutritionist for proper follow-up (see Fig. 3).

TABLE XI. APPROXIMATION OF EACH DISH TO THE IDEAL OF THE MACRONUTRIENT *M*

Alternatives	Prioritization	Macronutrient *M* Amount (grams)	Approximation to ideal (grams)
Dish 1	1° (First closest to ideal)	M_1	$\lvert I - M_1 \rvert = Apr_1$
Dish 2	2° (Second closest to ideal)	M_2	$\lvert I - M_2 \rvert = Apr_2$
Dish 3	3° (Third closest to ideal)	M_3	$\lvert I - M_3 \rvert = Apr_3$

IV. VALIDATION

The validation of the functioning of the current application was carried out in a private medical center of an unofficial nutritionist called "Sanamente", located in the district of San Juan de Lurigancho, Province of Lima, Peru.

For the validation of our proposal and evaluation of results, experiments were carried out, in which health professionals were involved. For the validation section, various tests were realized with the support of 8 nutritionists between 21 and 50 years old and 8 patients between 15 and 29 years old. In this part, the evaluated indicators were the diet plan creation process, the monitoring process and the satisfaction of our stakeholders (patients and nutritionists).

Two experiments were carried out, one with the traditional method and the other one with the application, in order to make future comparisons of results. Hence, the evaluation process was carried out through two different questionnaires (see Table 13 and 14). These questionnaires were designed so that the first 5 questions have similar indicators. In question Q1, the alternatives for representation scale 1 and 4, would be [5; 10[and [20; to more] minutes respectively, in which each alternative has a range of 5 minutes. Likewise, in question Q2, the alternatives by proxy scale 1 and 4, would be [1; 2] and [7; to more] monthly revisions respectively, in which each alternative has a range of 2 monthly revisions. Finally, in questions Q3, Q4 and Q5, the alternatives are represented according to Likert, in which 1 and 4 would represent "very good" and "very bad" respectively.

A. Experiment I.- Traditional Use

The traditional validation process follows the next steps: (1) Creation of the patient Profile, (2) Measurement of Anthropometric data, (3) Obesity assessment of the patient, (4) Creation of the Nutritional Plan for the Patient and 5) Completion of a questionnaire to both actors (see Table XII).

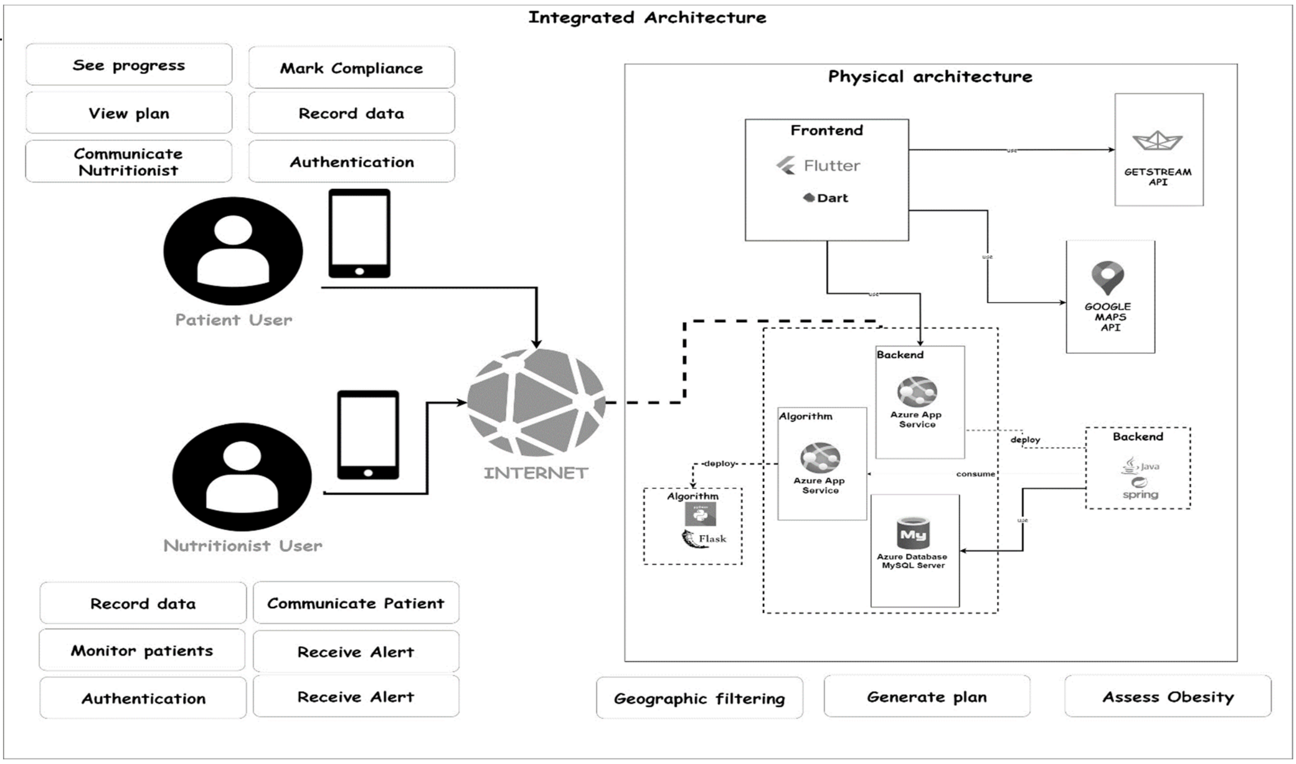

Fig. 3. Approach Integration Architecture

TABLE XII. QUESTIONNAIRE QUESTIONS TO MEASURE USABILITY IN THE TRADITIONAL WAY

#	Questions	Type	Person involved
Q1	Regarding the creation of the traditional diet plan, how long does it take to create and personalize it?	Closed	Nutritionist
Q2	In relation to the creation of the traditional dietary plan, how many check-ups do you perform on your patients per month?	Closed	Nutritionist
Q3	Regarding the creation of the traditional diet plan, how accurate is the diet plan recommendation for you?	Closed	Nutritionist
Q4	In relation to the creation of the traditional diet plan, what is your level of satisfaction?	Closed	Nutritionist
Q5	In relation to the creation of the traditional diet plan, what is your level of satisfaction with it?	Closed	Patient
Q6	In relation to the creation of the traditional diet plan, what aspects do you think should be improved?	Open	Nutritionist
Q7	In relation to the creation of the traditional diet plan, what aspects do you think should be improved?	Open	Patient

B. Experiment 2: Application Use

This experiment consists of performing a simulation of the creation and monitoring of dietary plans with the support of nutritionists and patients. For this, 3 points are necessary: (1) configuration of the implementation process, (2) creation and monitoring process of the nutritionist, and (3) completion of the questionnaire.

1. *Configuration of the implementation process:* (a)It starts with the software introduction, and (b)Configuration and implementation of the software on the mobile devices of the nutritionists/patients.

2. *Process of Creation and Monitoring of the Nutritionist*: The creation and monitoring process consists of the following steps: (i) registration of the patient's personal and anthropometric data (Fig. 4a), (ii) calculation of the body mass index (BMI) (Fig. 4b), (iii) assignment of a nutritionist responsible for the patient (Fig. 4c), (iv) selection of preferences (Fig. 4d), allergies and diseases of the patient (Fig. 4e), (v) creation of the dietary plan, (vi) customization of the dietary plan according to the judgment of the nutritionist (if required) (Fig. 4f) and (vii) monitoring of the patient made by their nutritionist. It is worth mentioning that the whole process of creation and monitoring with the application was carried out under the consent of the actors involved.

3. *Completion of the questionnaire:* The study was validated by experts, who used the application and gave their testimony about it. The experts contacted for this validation were nutritionists, specialized in obesity and overweight. The validation consisted of 3 steps: (1) Explanation of the purpose of the "FullFeed" application, (2) use of the application by the experts, and (3) preparation of the validation survey. The experiment was carried out separately with a duration of approximately 45 minutes per person, beginning with a brief explanation of the purpose of the "FullFeed" application.

For the simulation and evaluation of the application, the stakeholders were asked to perform the following steps: (a) creation of a profile to log into the system and obtain all the functionalities according to their role, (b) creation of the dietary plan according to the patient's preferences, (c) time monitoring by the nutritionist and finally, (e) the conduct of a survey with questions related to the usability of the system (see Table XIII).

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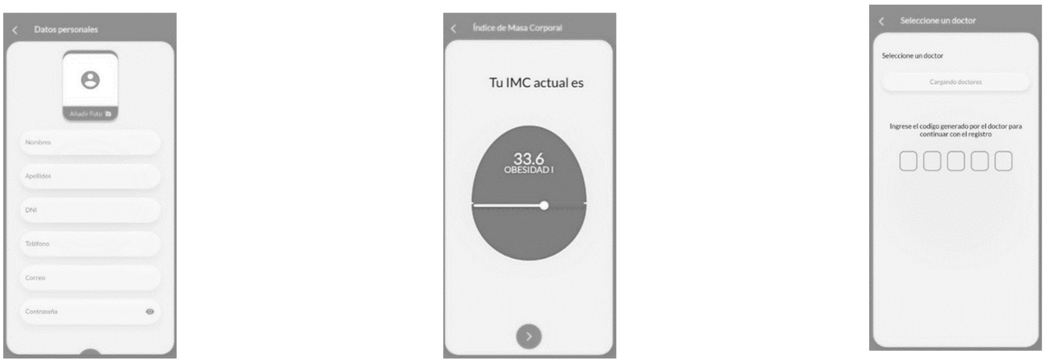

(a) *(b)* *(c)*

(d) *(e)* *(f)*

Fig. 4. Graphical interface of the application

TABLE XIII. QUESTIONNAIRE QUESTIONS TO MEASURE THE USABILITY OF THE SYSTEM

#	Questions	Type	Person Involved
Q1	In relation to the creation of the dietary plan with the FullFeed application, how long does it take to create and customize it?	Closed	Nutrition ist
Q2	In relation to the creation of the dietary plan with the FullFeed application, how many check-ups do you perform on your patients per month?	Closed	Nutrition ist
Q3	In relation to the creation of the dietary plan with the FullFeed application, how accurate is the personalization of the plan?	Closed	Nutrition ist
Q4	In relation to the creation of the dietary plan with the FullFeed application, what is your level of satisfaction?	Closed	Nutrition ist
Q5	In relation to the creation of the dietary plan with the FullFeed application, what is your level of satisfaction?	Closed	Patient
Q6	In relation to the creation of the dietary plan with the FullFeed application, what aspects do you think should be improved?	Abierto	Patient

V. RESULTS AND DISCUSSION

Fig. 5 shows the results of the survey on the creation of a dietetic plan in the traditional way (Experiment 1), carried out by the 8 experts (E1, E2, E3, E4, E5, E6, E7, E8) on the 5 questions (Q1, Q2, Q3, Q4, Q5) of the questionnaire.

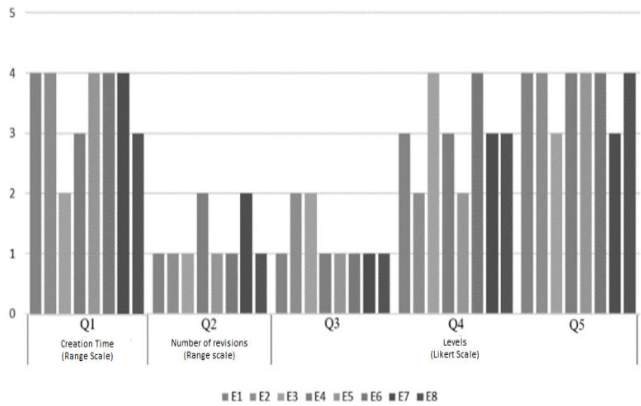

Fig. 5. Results of the survey on the creation of a dietary plan in the traditional way (Experiment 1).

Regarding the amount of time it takes to create the dietary plan (Q1), it was found that, on average, the experts gave a score of 4, which means that they take between 20 and more minutes to create a dietary plan. Likewise, in relation with the number of monthly revisions (Q2), the experts provided, on average, a score of 1, which means that they carry out between 1 and 2 monthly revisions. Finally, concerning the accuracy level of the dietary plan (Q3), the nutritionist's level of satisfaction (Q4) and the patient's level of satisfaction (Q5), it was observed that, on average, a rating of 1 (very good), 3 (low) and 4 (very low) was obtained, respectively.

On the other hand, Fig. 6 shows the results of the survey on the creation of the diet plan with the proposed application

(Experiment 2), carried out by the 8 experts (E1, E2, E3, E4, E5, E6, E7, E8) on the 5 questions (Q1, Q2, Q3, Q4, Q5) of the questionnaire.

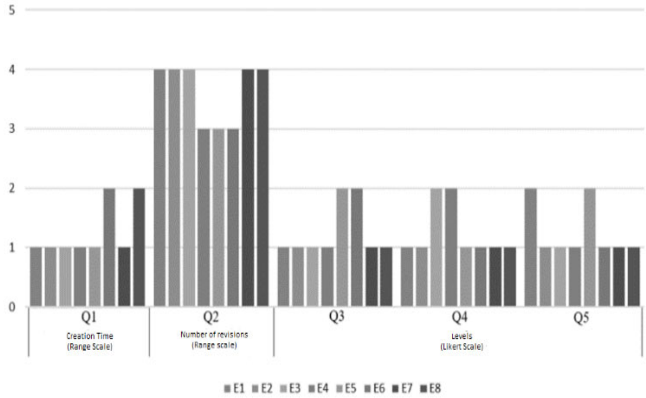

Fig. 6. Results of the survey on the creation of the dietary plan with the application (Experiment 2).

As for the time taken to create the dietary plan (Q1), it is shown that, on average, the experts provided a score of 1, indicating that it takes between 5 and 10 minutes to create a dietary plan. Also, for the number of monthly revisions (Q2), it was observed that, on average, the experts gave a score of 4, which means that it is possible to carry out from 7 to more monthly revisions. Finally, regarding the level of accuracy of the dietary plan (Q3), the nutritionist's level of satisfaction (Q4) and the patient's level of satisfaction (Q5), it was observed that, on average, a score of 1 (very good) was obtained for each one of the questions.

To summarize, Table XIV shows a comparison of the results obtained with the traditional method and the use of the proposed approach, regarding the time taken to create the dietary plan, number of monthly revisions, accuracy of the dietetic plan, nutritionist's satisfaction level and patient's satisfaction level. For instance, regarding the time to create the dietary plan (Q1), using the traditional method would take from 20 to more minutes, while with Full Feed would take from 5 to 10 minutes. Therefore, in a conceptual interpretation, this would mean that for each patient attended in the traditional way, there are 4 patients using the proposed application.

TABLE XIV. RESULTS COMPARISON

#	Traditional Method	Proposed Application
Q1	20 to more (minutes)	5 to 10 (minutes)
Q2	1 to 2 (revisions)	7 to more (revisions)
Q3	Very good (precision)	Very good (precision)
Q4	Low (satisfaction- nutritionist)	Very good (satisfaction - nutritionist)
Q5	Very low (satisfaction - patient)	Very good (satisfaction - patient)

VI. CONCLUSIONS AND FUTURE PROJECTS

In this study, a mobile application (Full Feed) has been proposed, implementing an Analytic Hierarchical Process (AHP) approach, for the assignation and generation of dietary plans. Five phases were defined: (1) definition of anthropometric data, (2) selection of macronutrients, (3) dataset definition of dietary dishes, (4) AHP algorithm definition and (5) design of the mobile application. For the AHP algorithm definition, a hierarchical tree was designed (Fig. 2), considering three levels: (i) the objective of the study (dietary dish recommendation), (ii) the criteria (macronutrients) and (iii) the alternatives (dishes).

To validate the study, two experiments were carried out in a private entity in Lima, involving 8 nutritionists and 8 patients. The process of the experiment 1 considered the following steps: (1) creation of the patient profile, (2) measurement of anthropometric data, (3) obesity diagnosis of the patient, (4) creation of the nutritional plan for the patient and (5) completion of a questionnaire given to both actors. And for experiment 2, we considered the next steps: (1) configuration of the implementation process, (2) creation and monitoring process of the nutritionist, and (3) completion of the questionnaire.

The results demonstrated that the proposed application had more positive measures or levels for all indicators (creation time, number of revisions, level of accuracy and levels of satisfaction) than the traditional method. By comparing the first indicator, it can be interpreted that with the implementation of the applicative, the number of patients attended per day would increase 4 times more. Similarly, in relation to the second indicator, it is evident that, with the use of the application, there is a more strict and continuous monitoring of patients, which promotes body weight control. Likewise, the third indicator proved that the application has an equal average level of precision to the nutritionist's criteria. Lastly, high levels of satisfaction were obtained for both the nutritionist and the patient through the fourth and fifth indicators.

Thus, the results obtained in all indicators were positive, and therefore it is highly recommended that the Peruvian public or private health sector use digital technologies to improve their efficiency in nutrition processes. It is important to note that the implementation and adaptation of the system will depend on their working environment, since it may be challenging for an environment with low digitization.

The limitation of the study was the prolonged time of weight variation in the patients. Therefore, for future work, the approach to the results could be changed, focusing more on the patients and their anthropometric data. To do this, it is necessary to sample anthropometric data from a group of people starting and ending a dietary plan. The result of the sampling would be the proof that the application complies with the loss of body weight in patients with obesity. In this way, the system would cover not only usability issues, but also the efficiency in the patient's results.

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