A Healthy Nutrition Model for Infants

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Declaration

I declare that this work has not been previously submitted and approved for the award of a degree by this or any other University. To the best of my knowledge and belief, the dissertation contains no material previously published or written by another person except where due reference is made in the dissertation itself.

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Date……………...

Approval

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Abstract

Accessing information on nutrition for a majority of young mothers in the sub- Saharan region has been marked with numerous challenges. The most common method for gathering nutrition information is by searching for the information on the Internet. This process of gathering information does not always result in providing the needed information and mothers also find the information unclear in many occasions. As such, this has resulted in widespread cases of undernutrition in infants due to poor feeding practices. The current technological platforms for disseminating nutrition education fail to focus on the unique nutritional needs of an infant. This research aimed at understanding the challenges faced by mothers in meeting their infant's nutritional requirements, to understand the methods and tools used to provide nutrition literacy and establish the data and information requirements for determining the nutritional value of foods for infants. The ability to feed healthy food begins with awareness of the nutritional value in food. A healthy diet is most important during infancy than during any other time of life because it impacts on brain growth, development of the nervous system, entire growth and development of the body and for eradication of diseases such as rickets and anemia caused by lack of essential nutrients. The study proposes the use of a nutrition model for infants for generating healthy meals according to their age. The proposed model made use of the guidelines as per the Recommended Dietary Allowance (RDA) which is provided by the institute of Medicine (IOM) and using rules determined the daily meals that would provide the required nutrients an infant needs. Agile methodology was used to develop the model, it allowed for a quicker release and subsequent user feedback. The model can be accessed through Internet browser both on mobile phone and on a computer. The model was tested through a simulation of various modules. Of the 10 participants that took part in this exercise, 6 were satisfied that the model fulfilled the intended functions of generating healthy meals for infants. 7 of the respondents also found the model easy to use. The model was therefore successful in offering nutrition expertise for infants.

Dedication

This dissertation is dedicated to my mother and daughter.

Acknowledgment

I acknowledge God's grace and favor for it through Him that I have accomplished this work. I wish to thank my supervisor Dr. Omwenga, for his invaluable and constructive feedback, and for giving his time generously. I wish to express my gratitude to Dr. Orero for his insightful comments. I wish to thank my dear husband for his love and unwavering support throughout the entire study period. I also wish to thank my friends for their encouragement and support to complete this work.

Abbreviations/Acronyms

AAP	American Academy of Pediatrics
ADM	Automatic Dietary Monitoring
DH	Diet History
EFR	Estimated Food Record
FFQ	Food Frequency Questionnaire
FR	Food Record
FRS	Food Recognition System
GHI	Global Hunger Index
GOK	Government of Kenya
ICT	Information Communication Technology
IFPRI	International Food Policy Research Institute
IOM	Institute of Medicine
NGO	Non-Governmental Organization
PDA	Personal Digital Assistance
RFID	Radio Frequency Identification
SDR	Spoken dietary records
SDR	Spoken Dietary Records
SVM	Support Vector Machine
TEE	Total Energy Expenditure
WFP	World Food Program
WFR	Weight Food Record
WHO	World Health Organization

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Chapter 1 : Introduction

1.1 Background of Study

Nutrition plays a pivotal role for the optimal growth and development of children. Infants and toddlers, for instance, depend entirely on their parents or caregivers for providing them with needful nourishment. There are numerous nutritional changes that occur in infants, especially during their first two years as they transform from a pure breast milk diet to one consisting of an assortment of foods (Levin, 2013) Feeding developing infants with the appropriate types and amounts of foods boosts and promotes their health. Kenya Demographic Health Survey (KDHS, 2014) reports that poor breastfeeding and inappropriate nutrition has adverse consequences for the health and nutritional status of infants. Thus, parents and caregivers have the mandate of ensuring optimal nutrition in their young ones at this time, as it is important in brain growth, development of the nervous system, entire growth, and development than during any other time of life.

Developing countries are the worst affected when it comes to the ability to measure nutrients in foods for infants. A survey by the World Health Organization (WHO, 2005) for instance, indicates that about 55% of total global deaths among children under-five years are malnutrition associated with developing nations. The International Medical Corps (2015) reported that Kenya's Global Acute Malnutrition (GAM) rate stood at 15.7%, while Severe Acute Malnutrition (SAM) rate stood at 2.6% in 2011. However, the overall prevalence of GAM falls under a "critical" situation which is slightly above the emergency threshold benchmarked by WHO. Currently, Kenya is working towards achieving its Vision 2030 blueprint in the health sector and more so it's nutrition indicator which is to halve the prevalence of underweight in children under-five years from 16.25% in 2015 to 8.125% in 2030 (GOK, 2007).

According to (Wing & Phelan, 2005) measuring nutritional value can be effective if caregivers and parents can write down daily intake of their children. The most challenging thing is obtaining valid measurements of dietary intake. Doubly labeled water (DLW) is currently considered as the gold standard way of measuring food intake though it has substantial limitations such as high cost and its lack of real-time applicability. The majority of methods for measuring nutrient intakes such as 24-hour recall, food frequency questionnaire, and paper-based food diaries are based on participants' reports. This is because participants are required by these methods to consistently remember food consumed in a given period and be able to accurately estimate the portion size. As such, these methods are limited by the greater possibility of biasness, error, participant burden, and cost and under-reporting. Various studies have indicated that these methods underestimate food intake by at least 37% (Boushey, *et al.*, 2009).

ICT has improved and eased the recording of dietary intake and both mobile and web-based applications exist in the market for measuring nutrient intake in foods for infants. With the growing knowledge and access to modern technology, this necessitates the need for an application that can help caregivers to measure nutrients in foods for infants. Given two groups for instance i.e. the smartphone and the traditional paper-and-pencil groups each with the aim of conducting diet-tracking (Årsand, *e t al.*, 2008), indicates that participants using smartphones and web- based systems with diet tracking/nutrient intake assessment apps will have more positive impact in measuring nutrient intake than participants using either note-taking functions on their smartphone or the use of paper-and-pencil diet-tracking method (Årsand, *et al.*, 2008). The available technology only gives a general description of measuring nutrients to all children without necessarily considering the individual nutritional status of a caregiver's child such as gender, weight-for-age, height-for-age, and weight-for-height, it also fails to give personalized feedback after daily dietary assessment.

1.2 Problem Statement

Infants are the most vulnerable to malnutrition since most of the growth and development processes take place at this stage of the lifecycle. Who & Consultation (2003) posits that during these vital years, infants require greater priority for the maintenance of their nutritional health.

Owing to the heightened global policy attention to the problem of poor nutritional attainment among children in developing countries, Kenya has been classified as one region that needs in-depth attention as far as nutrition needs among infants is concerned (WHO, 2010). Recent reports indicate that about 20% of all deaths and 20% of health loss among infants, toddlers and children under-five years in low-income countries is attributed to nutritional deficiency (Bowman, *et al.*, 2004).

Given that there are mounting concerns of infant nutrient intakes, there is a need for advanced tools for keeping personal dietary records that can accurately monitor a child's energy and nutrient intakes (Patrick, Griswold, Raab, & Intille, 2008). Most applications are unable to provide the optimal level that is sufficient to meet the nutrient requirement since they give a general formula without considering the individual child's status such as weight, height, health, and body response. As such, most children persist to sink deeper by being malnourished and nutrient imbalances irrespective of the availability of modern tools for a nutrient intake assessment. In light of these issues, an nutrition model for generating healthy meals for infants is proposed.

1.3 Research Objectives

The main purpose of this study is to develop a healthy nutrition model for generating healthy meals for infants

i. To analyze the determinants of the nutritional value of foods for infants.
ii. To review the existing frameworks, models and applications for nutrition.
iii. To develop an algorithm for generating healthy meals for infants.
iv. To develop a healthy nutrition model for infants.
v. To test the model.

1.4 Research Questions

i. What are the determinants of the nutritional value of food for infants?
ii. Which are the existing frameworks, models and applications for nutrition?
iii. How can an algorithm for generating healthy meals for infants be developed?
iv. How will a healthy nutrition model for infants be developed?
v. How will the model be tested?

1.5 Justification for the Study

This study is of paramount importance, as it will help in the integration of nutrition literacy among parents and caregivers. Since children are dependent on their parents or caregivers for providing them with needful nourishment, there is need to determine and accumulate data to help increase nutrition awareness and literacy among parents. The study sets out to avail the method that will supplement in understanding how nutrient intakes are to be measured in a child's food. This will help caregivers improve the nutritional status of their children, thus ensure reduced cases of under- nutrition.

1.6 Scope of the Study

The study will target parents and caregivers with children below the age of three years. For the purpose of developing a web application on nutrition monitoring, the researcher will target caregivers with access to phones or personal computers. The study will further focus on proteins, carbohydrates, vitamins, and minerals such as iron and zinc composition of foods.

1.7 Limitations of the Study

Food ration preparation affects the nutritional value of food in that some integral nutrients may be lost in the preparation of food as they are highly sensitive to either PH, oxygen, light, heat or a combination of these elements (West, Eilander, & van Lieshout, 2002). A nutrient intake assessment is affected by some cultural perceptions such as taboos on certain types of foods. Moreover, socio-cultural factors dictate nutritional characteristics and feeding behaviors (Dandyal, 2004). There may be other variables that influence the nutritional status of infants, but the researcher will limit herself to the above four mentioned variables only. It is expected there will be respondent's bias as some are likely to give responses that will favor the researcher's results.

Chapter 2 : Literature Review

2.1 Introduction

To understand the context and investigate the research problem, an empirical framework is presented in the form of a review of the determination of the nutritional value of food and the challenges faced in measuring the nutritional value of food for infants. Traditional methods for measuring nutrition are looked into. It discusses the features and limitations of nutrition systems that have been developed for nutrition recommendation. Based on the literature review, it gives a conclusion highlighting the research gap needed for a nutrition system for measuring nutritional value of food with a focus on infants.

2.2 Theoretical Framework in Nutrition

Becker's Microeconomic models of household production are the origin of the nutritional value assessment (Becker, 1965). In these models, households are seen allocating time and goods to the production of commodities either sold in the market or consumed at home. Grossman (1972), Behrman and Deolalikar (1989), Strauss and Thomas (1995) and Currie (2000) have since expanded and modified Becker's work.

According to (Becker, 1965) however, a child's nutritional status is a function of nutrition production and it relates to nutrient intake. Moreover, the quantity and quality of time a mother spends on healthcare-related activities determine a child's nutritional status (Becker, 1965). Further, Becker (1965) posits that the quality of child care time is in itself a function of the age of a caregiver, literacy level, experience, environmental factors, and own health status. According to the model, an increase in mother's income level increases procurement of medical care and food consumption thus raising a child's nutritional status. Nutritional value in food for infants is as a result of an assortment of combined factors such as the parents' or caregivers' behavioral factors, birth order, health, and nutrient intake. Thus a child's nutritional status is a function of; technology factors, nutritional input, biological factors, child's birth order, health, and childcare time.

2.3 Challenges in Tracking the Nutritional Value of Food

Obtaining nutritional information is quite challenging for mothers and caregivers. There are challenges with regard to the user such as; Mothers depend so much on nutrition recommender systems which pose numerous challenges in connecting with the user. Nutrition recommender systems are unable to give user-tailored recommendations owing to their difficulty in getting enough information about the user. Mothers tend to forget what they have fed their children, especially if they fail to write it down right after consumption. Moreover, others under-estimate and/or under-report what their children have eaten. Systems available to resolve such issues do not give mothers accurate nutritional information with regards to the meals consumed by their children (Robinson, *et al*., 2009). However, such systems are able to calculate a balance of the different kinds of food in a meal (i.e. Amount of vegetables, starchy foods, and proteins). But the fact that they don't give accurate nutritional information poses a great challenge mothers have in obtaining nutritional information. Most mothers have embarked on ceasing to use the available system which further triggers their inability to obtain relevant nutrition information. There are also challenges with regard to the nutrition feedback algorithms. For instance, a majority of the available algorithms do not provide important information such as user information (likes, dislikes, nutritional needs, and food consumed), a set of rules and regulations, and a database of recipes and their nutritional information thus they are unable to calculate user-tailored nutritional needs to mothers. If such user information, is not found in the available algorithms, then it becomes challenging for mothers to obtain tailor nutrition recommendations (Lioret, *et al*., 2013).

2.4 Nutrition in infants

The nutritional need for infants changes with time at different age stages. Therefore, for an infant to be healthy it is of paramount importance for parents and caregivers to take into account the various nutrient demands placed on their children's body these changes. Thus to meet an infant body's regular nutritional needs, they should be fed; (1) a wide variety of nutritious foods (2) water on a daily basis (3) enough kilojoules of energy with carbohydrates as the preferred source (4) essential fatty acids from foods such as avocado, nuts, oily fish (5) adequate protein (6) fat-soluble and water-soluble vitamins (7) essential minerals such as calcium, iron, and zinc and (8) foods containing plant-derived photo chemicals. As such, (WHO, 2005) identifies a varied diet that concentrates on fruits, vegetables, legumes, lean meats, whole grain, and dairy foods can meet these basic requirements.

i. Age

At age 0-6 months, breast milk/baby formula is enough to meet all the nutritional needs of the infant. However, the period from 6-36 months of age, breast milk is no longer enough to meet the nutritional needs of the infant. This necessitates the introduction of complementary feeding. WHO (2005) recommends adequacy of complementary feeding in that it should be given in amounts, frequency, consistency, and using a variety of foods to cover the nutritional needs of the growing child while at the same time maintaining breastfeeding.

Australia department of health (2009), recommends that a rice-based infant cereal is a good food for a 6 months old child to start with. WHO (2005) further indicates that infant cereal should be fortified with iron since it’s around this age that a baby store of iron begin to deplete. The other food type that follows is fruits and vegetables. The Dietary Guideline for Americans (2010) argues that common fruits such as stewed pear and apple, and vegetables such as potato, zucchini, carrot, and pumpkin should be offered first. A research conducted by (Sun, et al., 2016) stipulated the need for introducing meat, chicken, oat-based and wheat-based cereals, pasta, and rice from 7-8 months. Conversely, parents and caregivers can go ahead and introduce cooked egg between 10 and 11 months.

Nishida *et al*. (2004) conducted a study which revealed that dairy foods such as milk, yoghurt, and cheese contain at least ten (10) essential nutrients which are important for the growth and development of a child. These essential nutrients are: vitamin A, vitamin B12, zinc, potassium, protein, riboflavin, calcium, carbohydrate, magnesium, and phosphorus. As such, yoghurt, cheese and milk can be offered when a child is around 8 months old, although reduced fat milk is not suitable for children under 2 years of age.

The Institute of Medicine suggests that omega-3 fatty acids as important for an infant’s brain development. Further, it recommends consumption of at least 60g, 9.1g, 31g, and 500mg of carbohydrates, protein, total fat, and omega-3s each day for infants aged 0-6months. The IOM on the other hand recommends consumption of at least 95g, 11g, 30g, and 500mg of carbohydrates, protein, total fat, and omega-3s each day for infants aged 7-12 months (IOM, 2000).In order to calculate adequate intakes (AI) for infants aged 0-6 months, the Institute of Medicine has adopted milk volume of 780ml/day (IOM, 2002). From 12 months of age, however, milk consumption should be reduced to around 500-600ml/day and if fruit juice is offered, then about 125ml/day is recommended. Jelliffe and Jelliffe (1978) suggest that an infant aged 12 months and above needs 500mg/day of calcium and 14g/day of fiber.

ii. Weight-for-Height

Healthy infants come in an assortment of sizes. The American Academy of Pediatrics (AAP, 2016), report that children aged 0-6 months may grow 1.5-2.5cm in height and gain 140-200g in weight per week although some infants double these figures at about age 5 months. Moreover, from ages 6-12 months, babies grow about 1cm/month and gain 85-140g/week with a possibility of tripling their birth weight by about age 1 year. According to the American Academy of Pediatrics (2016), infants with normal weight-for-height require 110-150kcal/kg/day of caloric intake

iii. Gender

Both boys and girls require a nutritious diet for long-term health although gender plays a crucial role in determining the amount of nutrients needed. According to WHO (2005), feeding infants with the right proportion of nutrients helps parents and caregivers manage their children’s weight and supports their body functions. IOM (2000) on the other hand recommends 21-25g/day and 30-38g/day, 8-18mg/day and 8-12mg/day, 8-25g/kg/day and 12-32g/kg/day of calcium, iron, and protein intake for girls and boys respectively

Table 2.1 Recommended Dietary Allowance for an infant per day

Nutrient	**0-6 Months**	**7-12 Months**	**1-3 Years**
Energy (calories)	520-570	676-743	992-1046
Protein (grams)	9.1	13.5	13
Thiamin (mg)	0.2	0.3	0.5
Folate (mcg)	65	80	150
Choline (mg)	125	150	200
Vitamin A (mcg RE)	400	500	300
Vitamin D (mcg)	10	10	15
Vitamin E (mg alpha - TE)	4	5	6
Vitamin K (mcg)	2	2.5	30
Vitamin B5 (mg)	0.1	0.3	0.5
Vitamin B12 (mcg)	0.4	0.5	0.9
Vitamin C (mg)	40	50	15
Biotin (mcg)	5	6	8
Niacin (mg NE)	2	4	6
Riboflavin (mg)	0.3	0.4	0.5
Calcium (mg)	200	260	700
Iron (mg)	0.27	11	7
Zinc (mg)	2	3	3
Iodine (mcg)	110	130	90
Sodium (mg)	120	370	1,000
Potassium (mg)	400	700	3,000
Chromium (mcg)	0.2	5.5	11
Manganese (mg)	0.003	0.6	1.2
Copper (mcg)	200	220	340

Source: Dietary Reference Intakes (DRIs): Recommended Dietary Allowances (RDAs) and Adequate Intakes (AIs), Food & Nutrition Board, Institute of Medicine, National Academy of Sciences (NAS), 1998 - 2010.

2.4.1 Nutrition Databases

One of the global widely used nutritional databases is the database from United States Department of Agriculture (USDA, 2015). Here, data emanating from food producers, scientific studies, and various government agencies is compiled together with a policy put in place to update the data on an annual basis. The USDA composition of databases contains nutritional information on a variety of food items and food components and it ensures uniform organization and food description. Moreover, the USDA allows for the consistent naming of food entries thus enabling the system in refining the important data for accurate results and/or nutritional information. The USDA is widely used owing to its ability to give information on generic types of food which is nowadays mostly consumed by infants. This is important as it gives information on home cooked food by mothers and caregivers making it one of the most appropriate nutritional databases (Zanovec, *et al*., 2010). The Food and Nutrient Database for Dietary Studies on the other hand generates nutritional information based on the data of food items collected through national health and national examination surveys. This database comprises of many food items (O'neil, *et al*., 2014. The other widely used nutritional database is the semantics3 database whose data is collected from a variety of reputable online retailers whose products have Universal Product Codes (UPC) (Wang, Li, & Wiederhold, 2001). Unlike the USDA, semantics3 database is helpful for mothers and caregivers who do not necessarily prepare food for their infants on all occasions but rely on packaged food items at times.

Nutrient databases are continually being expanded and improved by the addition of new laboratory data, industry, universities and literature. However, limited nutritional analyses have been conducted on the various mixed dishes for which the Human Nutrition Information Service (HNIS) must provide nutrient values in food consumption surveys or for other purposes and it is, therefore, important to calculate nutritive values through the use of recipe programs (Bognar & Piekarski, 2000).

The steps towards recipe calculation entail, determining the weight in grams of each ingredient, determining nutrients in the specific weight of each ingredient from the standard Reference File, Applying retention factors for vitamin and mineral values when losses may occur during cooking, determining nutrients in the total recipe by summing nutrient values for the ingredients, adjusting the total values to account for changes in moisture and Fat during cooking, converting nutrient values for the total recipe to the 100-gram basis.

2.5 Dietary Assessment Methods

The appropriate tool for determining nutritional value depends on the purpose through which it is needed for. Such a purpose may either be measuring nutrients, foods, feeding and eating habits. There are many different methods that have been developed for determining nutritional value in food for infants. According to Rutishauser and Black (2002), methods designed to measure food and/or nutrient intakes follow various procedures. Which include, developing a report of all food consumed by an individual, reviewing and identifying the foods in such a manner that it is possible to choose an appropriate item from standard food tables. For in-depth studies, however, it calls for a duplicate portion of food to be chemically analyzed in order to find out the nutrient content, quantifying the portion size of each food item, determining the frequency through which each food is consumed, calculating nutrient intake, i.e. portion size (g) x frequency (f) x nutrient content/g, Rutishauser and Black (2002) further argue that it is possible for one to miss out on the steps (ii) and (v) while measuring food intake alone. As a matter of fact, if the aim is to assess nutrient intake of specific foods only, then developing a report of all food consumed by an individual may not be necessary. Quantification of the amounts eaten is however important if comparison with a food based target/recommendation is required (Rutishauser and Black, 2002).

Nelson et al. (1989) sees the main objectives of using dietary intake information in measuring dietary intake as (1) comparing the mean intake of groups, (2) determining the usual intake of an individual, (3) ranking individuals within a group, and (4) establishing the proportion of a population at risk of inadequate nutrient intake. Gibson (2005) posits that assessing nutrient intake at the population level is vital in understanding the etiology of certain diseases and the ongoing diet-disease relationship, monitoring and conducting surveillance of the diets of the population and formulation of recommendations for general health.

In the process of assessing nutritional value, there are many factors that affect the error of the measure. Beaton (1994) argues that the source and magnitude of the error depends on the method used. Self-reported method for instance ensures that various inherent factors in dietary intake assessment are capable of introducing error throughout the process of assessing dietary intake. However, errors in measuring nutrient intake are either random or systematic. Reliability of the measure is affected by random errors while the accuracy of the measure is affected by systematic errors (Bingham, 2007). Moreover, mistakes or discrepancies that occur while documenting nutrient intake are as a result of random errors while systematic errors are associated with the mode of data collection or some specific psychological and behavioral characteristics.

2.5.1 The 24 Hour Dietary Recall

This is the most common recall method in food and/or nutrient intake assessment. The 24-hour recall requires participants to report all foods consumed in the past 24 hours (Gibson, 2005). As such, participants are supposed to remember every single detail of food types and amounts of foods consumed. However, this method is prone to over and/or under estimation of macro and micronutrients. In Kenya for instance, there has been food omissions, food replacements, and poor estimations of food (Gewa, Murphy, & Neumann, 2009). Furthermore, various studies have reported a tendency of over-estimation of certain micronutrients among pre-school children in Kenya and under-estimation of macro and micronutrients among the elderly population (Kigutha, 1997). In Malawi, a validation study revealed the existence of under-estimation of energy and high-energy snacks and peripheral foods (Ferguson *et al*., 1995). In addition, further studies in Sub-Saharan Africa made a comparison between diets emanating from two 24 hour recalls, concluded that socio-cultural eating habits among communities limit food intake estimation since majority of people eat from common pot owing to lack of utensils. In the long-run, this leads to greater challenges in measuring food amounts and portion sizes. The best thing about this method is that it records low respondent burden, it is suitable for large scale surveys, and it can be administered by the use of a mobile phone. 24 hour recall method is however limited in that it is not effective in estimating portion sizes, single observation provides poor measure of individual intake, it is bias in recording good and/or bad foods, and it is memory dependent. However, irrespective of its many limitations, the 24 hour recall method asks respondents about all foods they/ their young ones have consumed in order to develop a better picture of macro and micronutrients that can be assessed. This is unlike other tools such as food frequency questionnaires that mostly focus on specific foods only.

2.5.2 Diet History (DH)

Historically, the diet history method was developed for use in research comprising three components; an element to assess daily eating patterns i.e. types and amounts of foods, a crosssectional tool to clarify list of food and nutrient intake, and a three consecutive days food diary (Burke, 1947). This tool was designed as a means of gathering, estimating nutrient intake, and providing dietary information on appropriate food preparation methods, feeding and eating practices. Gibson, 2005) suggests that the DH is quite labour intensive and time consuming as compared to other approaches. In the recent times however, DH has experienced numerous modifications to elicit relative estimates of nutrient intake (Ohl & Tapsell, 2000). Most health care facilities and clinical dietetic settings use a more condensed version of DH to elicit the usual nutrient intake of an individual over a long period of time thus making dietitian to comprehensively monitor dietary patterns and behaviors that relate to intake thus providing appropriate diet information to mothers. According to (Mensink et al., 2001); (Probst et al., 2008); (Slattery et al., 2008), more self-administered/automated versions have been developed which have similar reproducibility and validity.

2.5.3 Food Frequency Questionnaire (FFQ)

The food frequency questionnaire requires participants to point out all information about the specific foods consumed by an individual at a given time frame. It thus consist a list of foods and a selection of options relating to the frequency of consumption of each of the foods listed i.e. it takes into account times/day, week, month or year. It is designed in such a manner it can collect dietary information from a large group of people and they are self-administered (Shakarian & Haraldsdottir, 2001). FFQ dietary assessment method is useful in assessing specific types of foods and gives room for quick analysis of nutrient intake. As such, FFQ estimates amounts of Foods and nutrients consumed by an individual (MacIntyre, Venter, & Vorster, 2001). A study by the Women, Infants and Children (WIC) program asked mothers to stipulate WIC-recommended foods i.e. fruits, vegetables, calcium rich foods, iron rich foods, sweetened drinks, and sweets (Wojtusiak, Gewa, & Pawloski, 2011). In this study, WIC FFQ was developed amid including specific foods without necessarily providing a general overall intake such as energy consumed. The study concluded that as much as it was not possible to measure nutrient intake from this method, the method was however appropriate in gathering nutrient intake information on women, infants, and children. Further, habitual intake of a range of foods and specific dietary behaviors was reported.

2.5.4 Food Record (FR)

Food record method aims at assessing detailed dietary intake based on portion weights or estimates. Weighed food record (WFR) weighs all food items of an individual while estimated food record (EFR) requires an indirect measurement of food items. It is a prospective in nature and participants records all foods, amounts consumed in a particular period, fat content, cooking methods etc (Rollo, 2012). According to Gibson (2005), the requirement to weigh all items prior to consumption leads to a more accurate measure for estimating food and nutrient intakes of an individual. This method is however burdensome due to the need of measuring quantities consumed. A survey conducted by the British National Diet and Nutrition Surveys using 7-day WFRs in 2001 revealed that in the quest of reducing subject burden, 4-day EFRs was necessary (Poon, et al., 2010). However, recent work by (Fyfe, 2010) concluded that 3-day WFRs produced a comparable measure of habitual 7-day intake. It further found that shorter recording periods have a tendency of producing more accurate and appropriate estimates of intake (Fyfe *et al*., 2010).

Lindquist *et al*. (2000) suggests that the traditional use of this method requires high nutrition literacy and numerical skills as they are essential in comprehensively identifying and quantifying food items. (Lambert *et al.,* 2005) proposed the incorporation of video recorders, tape recorder, smart card technology, and personal digital assistants (PDA) in lessening the reliance of cognitive skills. Studies conducted by (Yon *et al*., 2007) and (Burke *et al*., 2011), concluded that the use of portable devices such as PDAs and mobile phones are more appropriate and give near accurate nutrient measurement as compared to traditional paper-based diaries. These studies further found that the use of the prospective method in measuring diet ensures self-monitoring and assessment of usual nutrient intake at an individual level.

2.6 Determining an Algorithm for Generating Healthy Meals for Infants

Research Council (US) Subcommittee on the Tenth Edition of the Recommended Dietary Allowances (1989, January 01) describes how RDA can be used to plan a meal. The age of infant and the RDA determine the Nutritional units needed by an infant in a day. Age is provided by the mother or care giver. The RDA is referenced from the Institute of Medicine. It is inform of a table which advices on the recommended nutrition levels to be provided to an infant in a day. Once the needed nutrients are determined, a meal can now be planned. The meal is evaluated by its individual food items. The nutritional level of each food item is calculated based on 100g. A nutrition database is used to reference the nutritional levels of the food items. To get the total nutrients an infant needs in a day, computations are done for the food items to realize the total nutrients. The specific food items that provide the nutrients needed and the right portions are key to successful determination of the feeding requirement for the infant. Computations are done to gather the total nutrients needed from various food items.

2.7 Expert Systems

An expert system is a computer program that solves the problems associated with a particular domain of knowledge by mimicking what a human expert does (Pigford & Baur, 1994). As such, expert systems are used to advice non-experts, especially in the events where a human expert is not available. Human experts are quite expensive to employ and at times it may be difficult to reach them, thus expert systems are used as a substitute. Further, they demonstrate mastery in specialized areas with the intent to give appropriate solutions (Gupta & Ritika Singhal, 2013).

Expert systems are widely used in medical diagnosis, providing financial advice, playing computer strategic games such as chess, diagnosing car engine problems, discovering locations for drilling water or oil, and in nutrition i.e. identifying food elements such as nutrients (Liao, 2005). Pigford and Baur (1994) argue that human experts are prone to making mistakes, unlike expert systems. However, expert systems don't easily adapt to a new environment, especially when the data presented is totally unexpected, are difficult to use, i.e. gives wrong advice if the non-expert user makes even the slightest mistake while using the system, and have no 'common sense' in that they are unable to notice obvious errors unlike a human expert (Pigford & Baur, 1994).

2.7.1 Components of an Expert System

The components of an expert system are comprised of the knowledge base, inference engine and user interface as shown in the Figure 2.1 (Hazman & Idrees, 2015). The non-expert user queries the expert system either by asking questions or rather answering questions that the expert system asks. This is done by the user interface component, then the inference engine component uses the non-expert user's query to search for an appropriate solution in the knowledge base component.

The knowledge base component, on the other hand, gives the non-expert user advice through the inference engine at the user interface component (Hazman & Idrees, 2015).

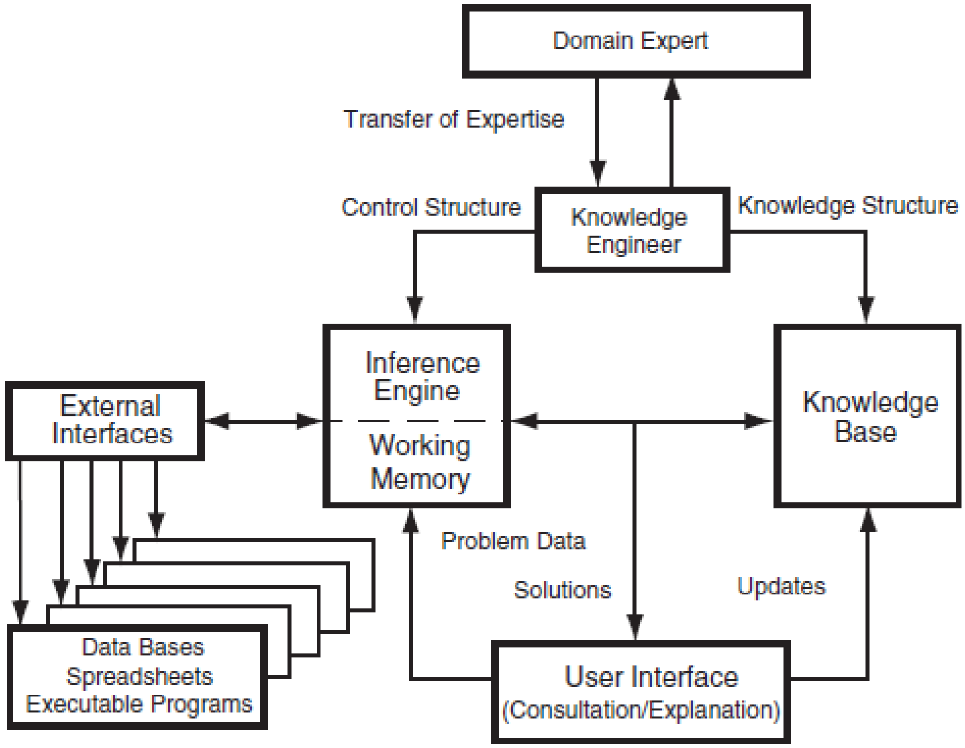


Figure 2.1 Components of an Expert System (Hazman & Idrees, 2015).

2.7.2 Knowledge Base

A knowledge base is a collection of rules, standards, procedures, and facts. The standard knowledge base is created from all the information that has been provided by the human expert. It acts as storage for intrinsic data that is to be applied in the problem domain. The model, knowledge base will consist of Recommended Dietary Allowance data for infants. It will also store user characteristics such as name and age. This will then be used in the if-then analysis.

2.7.3 Rule Base Reasoning

The rule base contains all rules that require appropriate reasoning. Rules are in the form of IF condition and THEN action. They relate facts in the IF (antecedent) part of the condition to some action which is the THEN (consequent) part of the condition. Rules can be chained together such that the antecedent is joined by a keyword AND (conjunction), OR (disjunction) or rather a combination of both (Dymova, Sevastianov, & Bartosiewicz, 2010). Below is an example of the "if… then "analysis of the above nutrition information.

R1. If infant < 6 months, then A

R2. If infant >6months and <12 months, then B

R3. If infant >12months and < 36 months, then C

The rule base reasoning holds that a rule is triggered if and only if all the conditions are satisfied and the consequents are shot (Dymova, Sevastianov, & Bartosiewicz, 2010).

2.7.4 Inference Engine

An inference engine defines the steps used in solving the nutrition problem. As such, it uses the non-expert user's query to search for an appropriate solution in the knowledge base component and manipulates it using algorithms to provide solutions to the problems. The inference engine incorporates the use of either forward - chaining or backward - chaining to bring about an appropriate solution. Forward - chaining uses the readily available data and inference rules to get more data from the user until the intended result is attained. Forward chaining goes through the inference rules until it picks on where the antecedent (if clause) is known to be true. When the intended rule is found, the engine can call on the consequent (then clause). This results to the addition of more information to its original data (Togai & Watanabe, 1986). Given that the model is using data to arrive at its conclusion, forward chaining is thus explained.

2.7.5 Working Memory

The working memory defines the steps taken in the inference engine sequence needed to achieve the objectives of the system. The working memory consists of accumulated facts and/or data for the specific problem under investigation. The model is expected to retain all the concluded combinations and use them for prediction purposes. Here, the "if then" analysis is applied.

2.8 Existing Frameworks, Models and Applications Used in Nutrition

There are mounting concerns of infant nutrient intake; there is therefore a need for tools for keeping personal dietary records that can accurately monitor a child's energy and nutrient intakes (Patrick, Griswold, Raab, & Intille, 2008). Most tools are unable to provide optimal level of accuracy that is sufficient to meet the nutrient requirement since they give a general formula without considering individual child's status such as weight, height, health, and body response. Below is a discussion of the existing mobile and web applications on nutrition.

2.8.1 The Log-a-meal Application

This is an application that used images to assess the nutritional level of food. Its user captures an image, and then the system breaks that image down into visual attributes. These features, of different complexity, range from something as simple as a line or a color, to the shape of a grain of rice. This application is able to learn the type of food it is by studying its attributes. To make this happen, a machine learning models that is intelligence-based is optimized for food. By training the models with lots of pictures of food, they develop their own understanding of what the key visual features define different foods – whether it is a distinctive singular item like an orange, or an elaborate recipe. The underlying technology in this case is artificial intelligence in the form of machine learning. This tool just assesses the nutrition level of food but does not give the recommended portion for an individual. (Ackers, 2016)

2.8.2 SmartPlate Application

This is an application that tracks what you eat. It is designed to visually determine the food placed on it, weigh the portions, and then report back calorie and nutritional data via a smartphone app. The SmartPlate also uses advanced machine learning to better identify foods as more and more people use the platform. The application shows 99 percent accuracy with many foods, and can determine the difference for example between white bread and wheat bread, and pasta with marinara sauce and pasta Alfredo. The technology used in this application is smart, integrated with web interaction and some modules are linked with the android operating system which the springboard of the application. This proposed model calculates the nutrients in food first so as to recommend the portions of food needed to satisfy the recommended nutrient intake for an infant. (Thomas, 2016)

2.8.3 UM Application

UM is a smart food advisor that tracks and analyses what you eat in order to provide personalized food recommendations. UM.AI says it exploits cutting edge technology in semantic and machine learning to structure more than 2 billion food data points in a logical and easy to use manner. The user just tells UM what they had, and then it processes the data. The system is more of an intelligent architecture for which the underlying is machine learning. The syntax and semantics used are purely driven by the system. The logical integration of the components in the application is what makes it intelligent. The disadvantage of this application is that it heavily relies on machine input rather than human input hence high dependency on the system. This rules out the aspect of it being user friendly. In order to personalize the application for individual needs, personal data such as age, health status of the individual and weight is needed. The proposed model enhances the idea of personalizing meals for according to the required needs based on age. (Thomas, 2016)

2.8.4 Nuritas Application

Thomas (2016) describes the Nuritas application, which provides access to the most-health benefiting components within foods, called bioactive peptides. Nuritas combines artificial intelligence and DNA analysis to discover novel and active peptide ingredients with scientifically proven health benefits, which include: anti-inflammatory activity, antimicrobial activity, muscle recovery enhancement, skin anti-aging solutions, and the potential management of blood sugar levels for type 2 diabetics. The bioactive peptides can be used in a range of products including functional and medical foods, pharmaceuticals, dietary supplements, as well as cosmetics and personal care. The intelligent bit of this application is that it works with neural networks that are interlinked and the combination gives the ultimate weighted result. This application gives personalized recommendations of food based on the health status of the user, it therefore requires health information of the user such as DNA. The major concern with this application is security and privacy issues as it subjects the user to revealing personal medical details, it also requires medical procedures to be done such as extraction of blood and DNA which can be uncomfortable for many users. The proposed model is infant focused and thus does not require to be intrusive in gathering personal medical history.

2.8.5 Nutrino Application

Nutrino and IBM Watson have developed the Nutrino Application to provide expectant mothers with real-time science-based, personalized and contextual nutrition advice (Thomas, 2016). The Nutrino App combines Nutrino's nutrition insights platform with Watson's natural language capability and deep question and answer capability to offer personalized meal recommendations and 24/7 nutritional support. The major disadvantage with this application is that it is quite complex and the graphical user interface is also complicated. It requires a lot of training for a user to easily interact with it

2.8.6 Calorie Counter & Food Diary

MyNetDiary's Calorie Counter and Food Diary method is a mobile diet and fitness coach. You enter your calories and exercise each day, and the app will do the rest, such as compare your calorie intake versus output. You'll also receive tips and information based on goals you set. You can sync it with a number of other fitness and diet devices and keep all your data in one place. This app keeps track of diet, exercise, calories, water intake, your measurements, and the vitamins and minerals you are getting. Everything you need to get healthy and stay healthy, in one easy to use.

Figure 2.2 Calorie Counter and Food Diary (10 best Android diet apps and, 2017)

2.8.7 NutriSonic Expert System

NutriSonic is a web application system that allows users to select a recommended general and therapeutic menu. Hong *et al*. (2008) suggests that the NutriSonic Web Expert System, helps in meal management and nutrition counseling by analyzing user's nutritive changes of his/her selected days and food exchange information with simple data transition (Hong, *et al*., 2008). The program plans meals for patients suffering from diabetes, obesity and other diseases for diet therapy. The system analyzes user's nutritive changes by manipulating food meals and menus and searches in the database that has already been developed. The expert inputs and stores a meal database and generates the synthetic information of age, gender and therapeutic purpose of the disease. The meal planning continues to grow after investigation and analysis of user's needs.

The system architecture of the application consists of user information details database and expert system database on MySQL platform. It runs on a windows operating system and sits on Linux servers (Hong, *et al*., 2008).

2.8.8 Nutrition UCR

Nutrition UCR is a mobile model expert system designed to aid in diagnosing, controlling, and monitoring human nutrition. It assesses the nutritional condition of the user by analysis his/her physical characteristics such as weight and eating habits and makes recommendations for attaining the required nutritional status and finding a balanced diet. The system recommends a list of ideal places to eat, offers healthy meals according the recommended diet of the user. The system generates alerts and challenges on a regular basis and it frequently motivates the user to always embark on using the application, thus improving his/her nutritional habits (Quesada & Jenkins, 2013). The system allows for interaction with Google maps, it shows you the location of the cafeteria and the route to use to get there. Once a cafeteria has been selected, the system allows for one to explore the menu offered and for each of the meals gives a detailed nutritional description. It allows you to select a menu from any one of the available cafeterias and gives the nutritional information. The system is developed in Java on android using a service-oriented architecture. It was recommended that, the knowledge- base be expanded to include more specialized nutrition information and nutrition experts validate the information (Quesada & Jenkins, 2013).

2.8.9 Expert system for Children

This is a web-based expert system aims at recommending nutritious meals to children of a certain age group, be it a toddler, preschooler, grade-schooler or a teen. It determines the required nutrition intake by using the recommended calorie intake per each age stage. It requires the user to enter their age, gender and level of activity and in turn it recommends a meal schedule that gives the required calorie intake per day. A web application was made for the system, the knowledge base was implemented using mini knowledge share and Reuse tool (MiniKSR) while the control of the system and user interface were implemented by Visual Basic.net (Microsoft Visual Studio 2010). For future works, they recommend a bilingual interface that provides a more variety of food based on user taste and preference (Hazman & Idrees, 2015).

2.8.10 Dietos Feedback System

This is a web based application system that provides individualized nutrition recommendation based on one's health profile. The user is required to fill in a questionnaire that is used to generate a health profile. This filled questionnaire is interlinked to the answers pertaining to the solution for the ailment such as what food to eat or avoid. Food filters are generated in this first stage of health profiling. Agapito *et al*. (2016) posits that the system graphical interface is written in HTML5, CSS, and JQuery while the server sides of data querying and presentation are written in PHP. For future work, they recommend to add the functionality of the application to send feedback in real-time once it receives the patient's laboratory results and also to add the variety of foods as it had only focused on Calabrian typical foods (Agapito, *et al*., 2016).

2.9 Conceptual Framework

This conceptual framework explains interlink between the web application and end user (parents and caregivers). Bogdan and Biklen (2003) recognizes a conceptual framework as a basic structure consisting of specific abstract blocks that represents the experiential, observational, and analytical aspect of the system being developed. As such, it is a set of broad principles and ideas extracted form related fields and used to mak*e* a structural presentation. The client (end user) enters infant's personal data, this includes name and age. Age and RDA values obtained from Institute of Medicine and Nutrition data from USDA are the input variables used to determine a healthy meal schedule for an infant.

Figure 2.5 is an illustration of the conceptual framework.

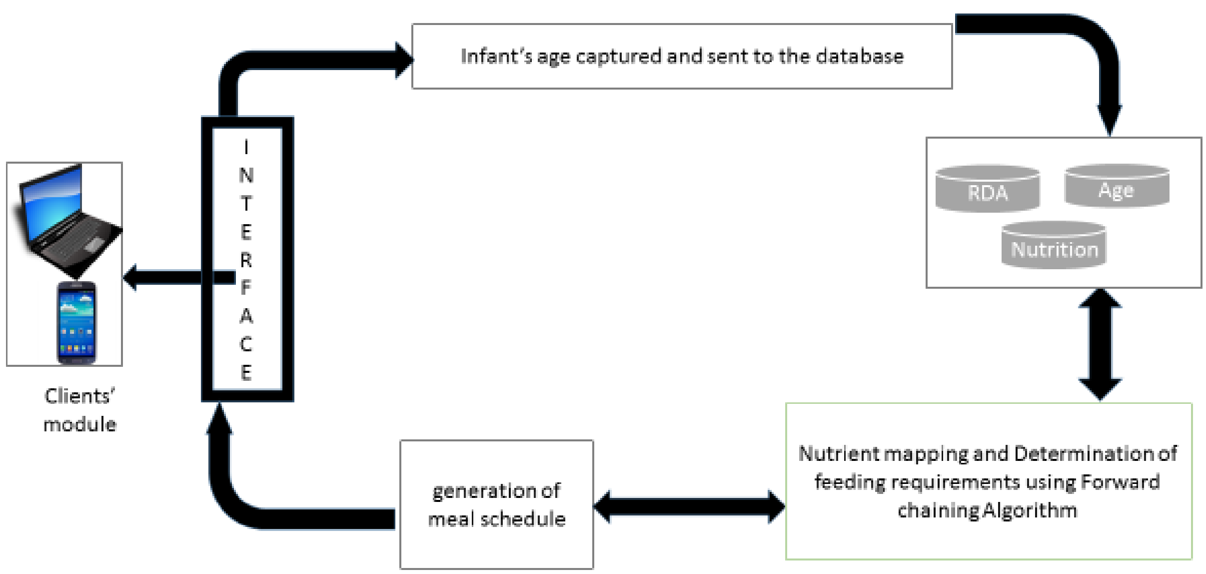


Figure 2.3 Conceptual Framework

2.10 Summary

The nutritional need for infants' changes with time at different age stages. Therefore, for an infant to be healthy it is of paramount importance for parents and caregivers to take into account the various nutrient demands placed on their children's body by these changing dynamics. Malnutrition has become a concerning issue especially to children under five years. Whether they are underweight, overweight or normal weight, some children are still malnourished and are lacking the main functional nutrients for the human body to develop physically and cognitively.

This study proposes a web- based nutrition model for generating healthy meals for infants. Using this healthy nutrition model, and upon infant registration, the caregiver logs in and searches for a recommended meal schedule. These meal schedules are arrived at after the model has synthesized the age information of the infant and referenced the nutrients the infant should be fed with on a daily basis. A nutrition database provides the meals from where these nutrients are sourced.

While systems such as applications discussed in this chapter are relevant in their own way for nutrition, none focus on the needed nutrition requirements of the infant. The proposed model attempts to bridge this gap by looking at the recommended dietary allowance for an infant per day as advised by IOM

Chapter 3 : Research Methodology

3.1 Introduction

This chapter presents the research methodology used in the study. A research methodology is a systematic guideline of a set of methods used in addressing a particular research problem (Kothari C. R., 2004). This chapter describes research design, population and sampling techniques, data collection instruments, data analysis and presentation, system development methodology, research validity and reliability instruments. As from the previous parts, the purpose of this study is to examine the perceptions of nutrition regarding the quality and condition, maintenance, improvement, utilization, and renovation of existing nutrition applications and frameworks. In that case, this chapter defines the scope and extent of the research design as well as the methods that are implemented to acquire the necessary and diversified data to answer the main research questions.

3.2 Research Design

The research design is an outline that is used as a road map for collecting, measuring, and analysing data. The study employed both qualitative and quantitative research designs. The researcher was convinced that these research designs would help solve the daily nutrition problems that mothers and caregivers face while feeding infants. The qualitative research design was used to get a clearer understanding of the experiences mothers and caregivers have while assessing nutritional value information. Quantitative research design, on the other hand, was used to identify the exact number of caregivers who have used other mobile or web-based nutrient systems and to establish the number of mothers/caregivers who would consider using the new system, i.e. nutrition model for generating healthy meals for infants. Moreover, quantitative research design would also help in identifying the number of people who thought the new system was a splendid idea worth considering (Shuttleworth, 2008).

3.3 System Development Methodology

System development methodology is a sequence of operations that is used to develop a system in a manner which allows it to be completed within deadlines and the quality of the system is maintained as per the requirement standards (Shubhmeet, 2015).

Due to time constraints, this research adopted an agile method of software development life cycle (SDLC). Agile methodologies are defined to be a continuous delivery of software through iterative and incremental development so as to attain customer satisfaction (Shubhmeet, 2015). Figure 3.1 illustrates the steps that this study followed in achieving its objectives. Step one was requirements which entailed collection of the system's features and the requirements of each specification. Step two was architecture and design which defined the architecture and design of the system. Step three was development which entailed evaluation and implementation of the system. Step four was test and feedback which entailed system improvement.

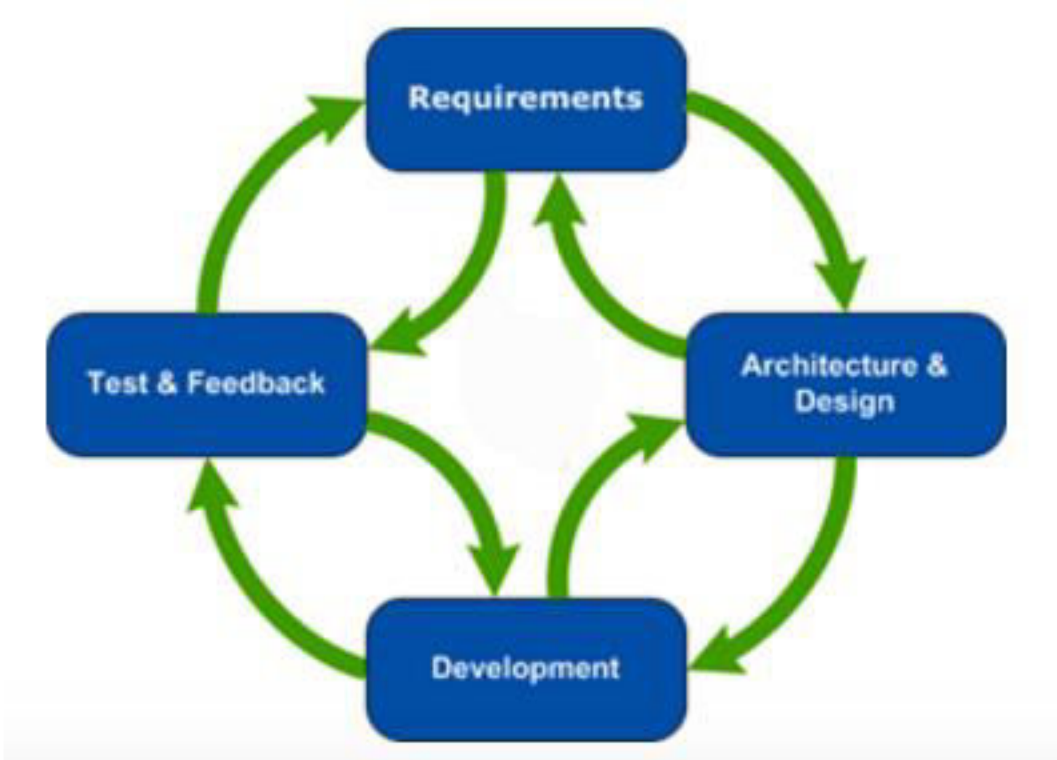


Figure 3.1Agile Method of Software Development Life Cycle (SDLC)

3.3.1 System Analysis

In the information system development section, three approaches are used; (1) data-oriented approach, (2) process-oriented approach, and (3) object-oriented approach. Both the data-oriented and process-oriented approaches emphasize specifically on either data or process. The object-oriented approach (OOA) on the other hand, integrates both data and process into constructs called objects. These objects are the entities which represent relationships and methods that are necessary for solving the research problem. The scenarios of the interactions between user and system are described using use-case and class modeling (Charles, *et al*., 2005). This scenario helps to model the data. This phase was used in planning the system and software design based on the requirements specified.

3.3.2 System Design

The object requirements in the system design were defined, identified, and refined using object-oriented design (OOD). For general conceptual designing of the software systematic, design class diagrams were employed. The design class diagrams incorporate comprehensive modeling, which helps in translating the model into programming code (Huda, Arya, & Khan, 2014).This study adopted design class diagram so as to embrace classes that entail the main methods and specifications of the system. Moreover, the researcher used Entity Relationship Diagram (ERD) which is a graphic used to demonstrate the relationship between objects, users, events, and concepts within a system (Cagiltay, *et al.,* 2013). Conversely, the researcher used ERD to develop feeding techniques and the relationship between the system and nutritional value.

3.3.3 System Implementation

The development languages used to create the model are PHP, CSS, JavaScript, HTML and MySQL database. PHP was used to execute the logic. PHP and JavaScript were used for validation and for ensuring the system is dynamic. MySQL was used to store the data and the knowledgebase generated.

3.3.4 System Testing

This study used usability testing to test the functionality of the system. The usability testing entails system testing and validation of system components on each screen e.g. text inputs and buttons, validation of navigation flow, ease of navigation, responsiveness and user friendliness (Belatrix, 2015)

3.4 Population and sampling

This research was conducted in Nairobi County, Kenya. The sample population targeted the parenting population aged between 21 and 50 years. As of December 2009, this population stood at approximately 1, 336, 694 people. (KNBS, 2010).

Since the target parenting population is extremely large, the research employed a probability sample technique, where the sample population was chosen at random. This sampling technique allows each person to have an equal probability of being sampled. To obtain the required sample size equation 3.1 was used.

$$\mathbf{n} = \frac{\boldsymbol{NZ^2 \times 0.25}}{[\boldsymbol{d^2 \times (N-1)}] + (\boldsymbol{Z^2 \times 0.25})}$$

Equation 3.1Sample Size Equation

Where:

n= sample size

N= Total population size (1, 336, 694)

d= Precision level (0.10)

Z= Level of confidence (95%)

$$\mathrm{n} = \frac{1{,}336{,}694 \times 1.96^2 \times 0.25}{[0.1^2 \times (1{,}336{,}694 - 1)] + (1.96^2 \times 0.25)}$$

Therefore, n = 96.033172

96 Participants were issued the questionnaire.

3.5 Data Collection Instruments

An online questionnaire was used as the main data collection procedure. The researcher administered online questionnaires to collect information regarding the need for the proposed system and the user requirements from the participants (Appendix A). Questionnaires are ideal because they can reach a wide number of people (Kothari, 2004).

3.6 Data Analysis and Presentation

In order to validate the study objectives, user and system requirements driven context analysis was used. Research objectives and user requirements helped to determine the initial development scheme. For the initial codes, a directed approach analysis starts with relevant research findings of what is known (Hsieh, 2005). The information that cannot be categorized is noted and kept for evaluation to determine if it represents a new category or a subcategory of an existing code. This method was preferred because the primary classification does not interfere with the identification of important objectives. The method also assists to dwell on questionnaire questions which eases data analysis. The data analyzed was presented using pie charts, bar graphs, and tables which provided a visual representation of the quantitative data and allowed for comparisons and correlations within the data.

3.7 Research Validity and Reliability

Research quality aspects is the degree to which the research was carried out correctly. Validity and reliability were used to test the quality aspects.

3.7.1 Validity

The research validity determines the criteria for assessing how effective the research design has been in terms of implementing measurement methods that accurately capture the data required to address the research questions (Kothari, 2004).

The researcher embarked on conducting a pilot study prior to the main study so as to assess the validity of the research. The study aimed at collecting data necessary for developing a model for generating healthy meals for infants. This study targeted a population of ten parenting mothers and caregivers. The questionnaires emailed to them addressed issues such as systems they use to assess nutritional information, whether these systems are effective, and whether there is a need for improvement of those systems. Further, the researcher proposed her system to the population to see their reception of the same. The pilot study found that there is a great need for a user-friendly nutritional system and the target population pointed out that the new system would be of immense value to them and other future users. The findings formed the basis for the main research and the content validity chosen matched the test content.

3.7.2 Reliability

Reliability is a measure of the degree to which data collection instruments yields consistent results over a given period. As such, a reliable data collection tool is one that tends to produce the same results when used more than once (Mashburn, *et al.*, 2014). The study employed inter-rater reliability, which measures the level to which information gathered by different tools of data collection is done in a trustworthy manner. Inter-rater reliability was also considered since it ensures the procedure incorporated in data collection is solid and with the assurance of obtaining the same results repetitively (Gwet, 2014). The researcher attained research reliability by distributing questionnaires to the respondents to fill and in a span of one week repeating the same. The researcher cross checked the correlation between the two which formed the basis for proceeding with the study.

3.8 Ethical Considerations

To uphold ethical standards, the researcher obtained consent from the selected respondents before the survey. The data gathered was treated with the utmost confidence and used solely for the purpose of the study. The questionnaires had a disclaimer.

Chapter 4 : System Design and Analysis

4.1 Introduction

This chapter discusses the design structure of the proposed solution which incorporates the user requirements gathered through interaction with the potential users of the model in the previous chapter , data analysis of those findings are presented here. The design structure of the model was achieved by drawing diagrams such as use case diagrams, sequence diagrams and context diagram using Unified Modelling Language (UML).

4.2 Results from Questionnaire

In order to gather the user requirements, questionnaires were administered to mothers. The results were analyzed and presented using pie charts and bar charts as shown.

4.2.1 Age group of respondents

Figure 4.1 illustrates the ages of the respondents.

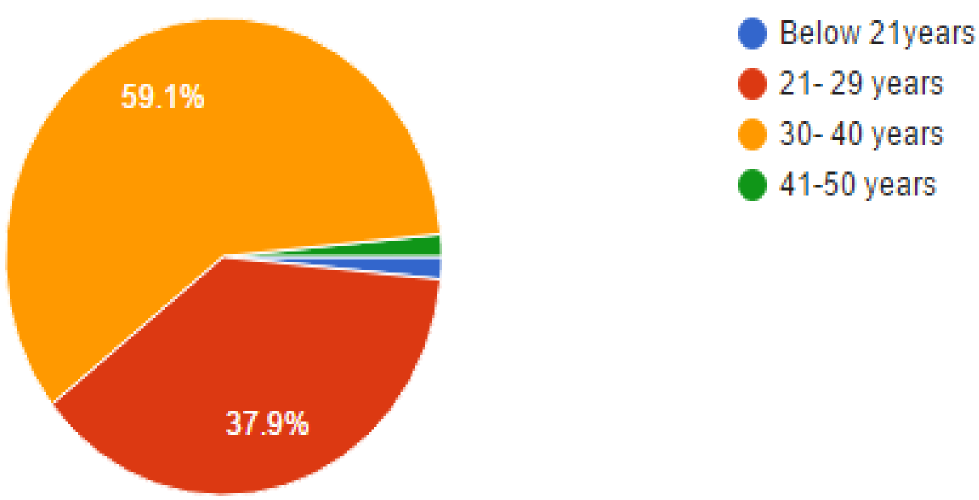


Figure 4.1Age group

4.2.2 Level of Education of Mothers

Figure 4.2 illustrates the educational level of the respondents.

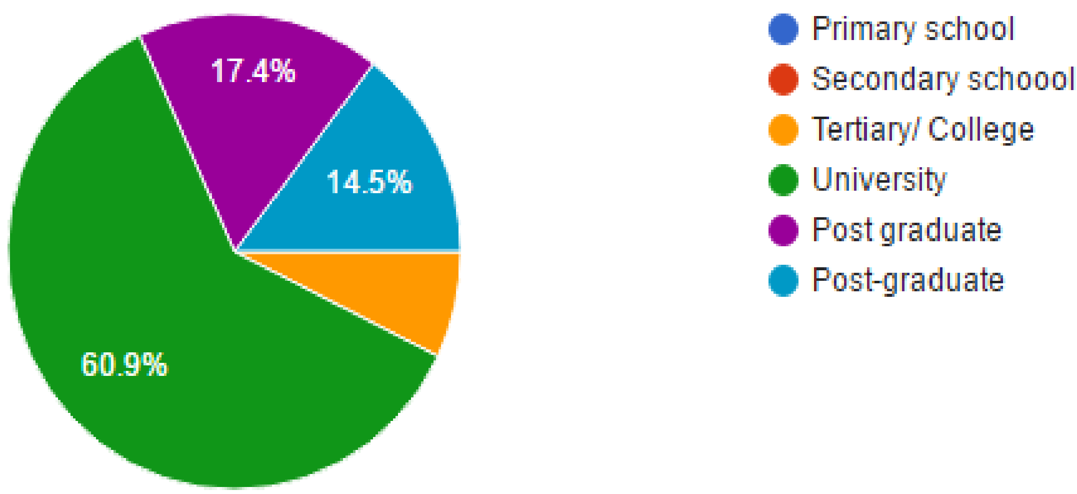


Figure 4.2 Level of Education

4.2.3 Awareness of The Nutritional Content of the Food Fed ToThe Infant

Figure 4.3 illustrates how aware the respondents are on the nutritional contents of the foods they feed their infants.

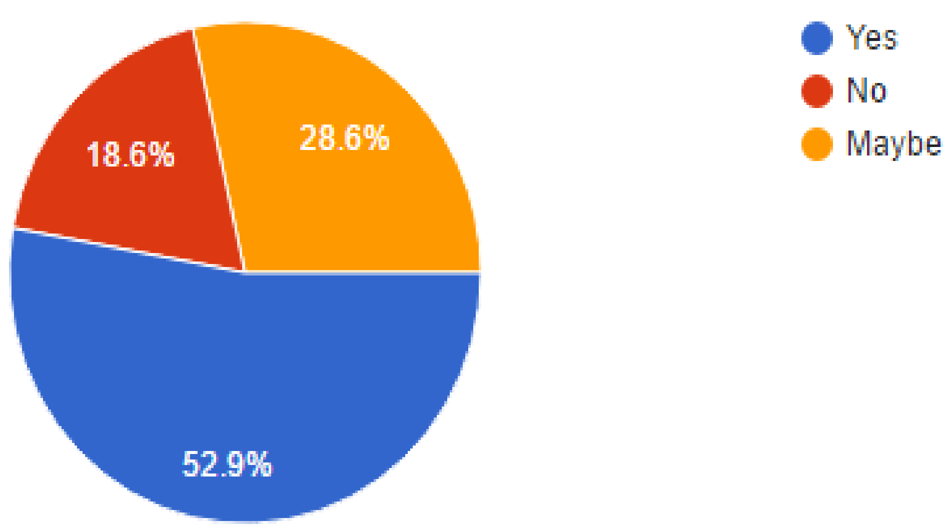


Figure 4.3 level of awareness in nutritional Content of food

4.2.4 Challenges Mothers Face in Gathering Nutritional Information for Infants

Figure 4.4 illustrates the common challenges that the respondents face in feeding infants.

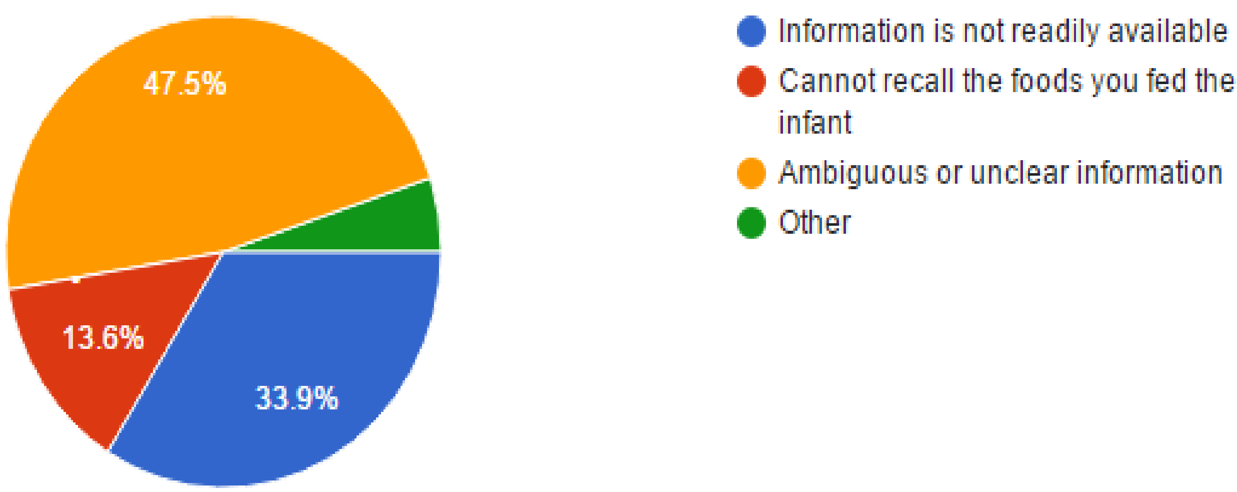


Figure 4.4 Challenges mothers face when gathering nutrition information

4.2.5 Source of Nutritional Advice for Mothers

Figure 4.5 illustrates the sources of nutrition advice for the respondents.

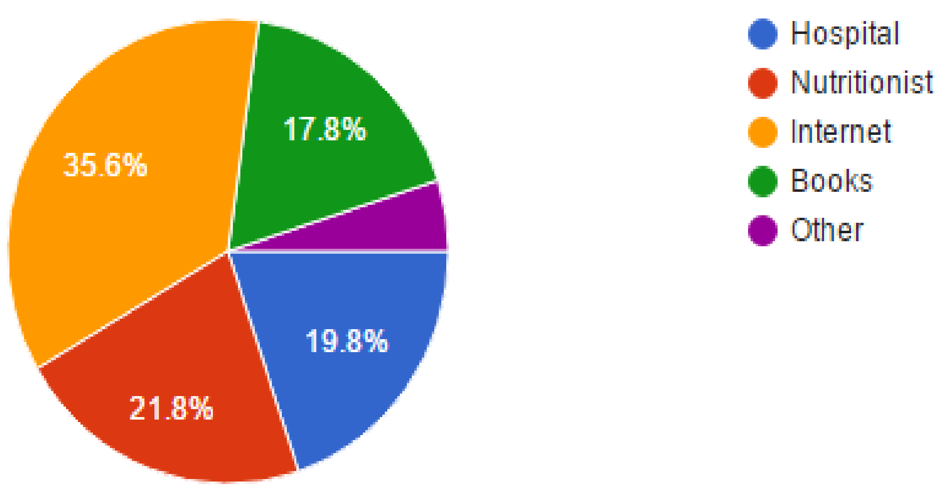


Figure 4.5 Source of nutrition advice

4.2.6 Importance of Nutritional Information for Infants

The question sort to find out if the respondents were aware of the value of good nutrition for infants as illustrated in Figure 4.6.

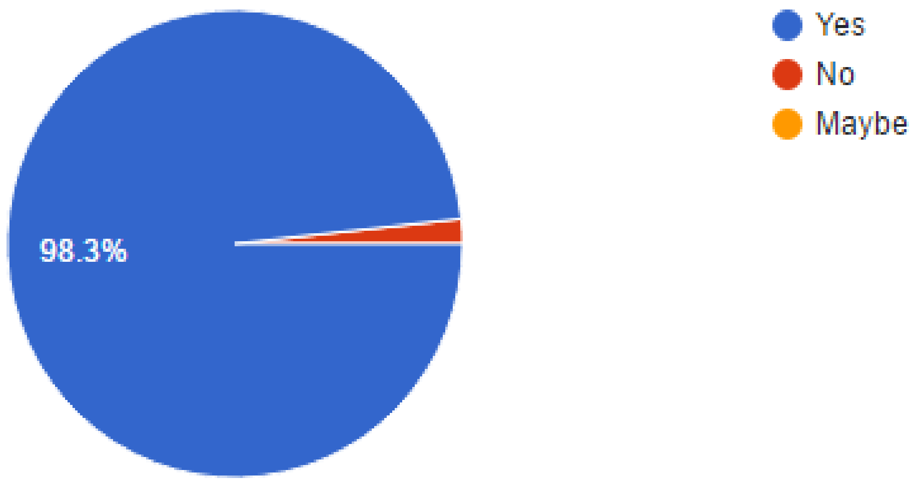


Figure 4.6 Response on importance of good nutrition in infants

4.2.7 Catagories of Nutrients Fed

This question sort to find out if respondents fed essential macronutrients. Figure 4.7 illustrates the number of respondents and what nutrients they fed.

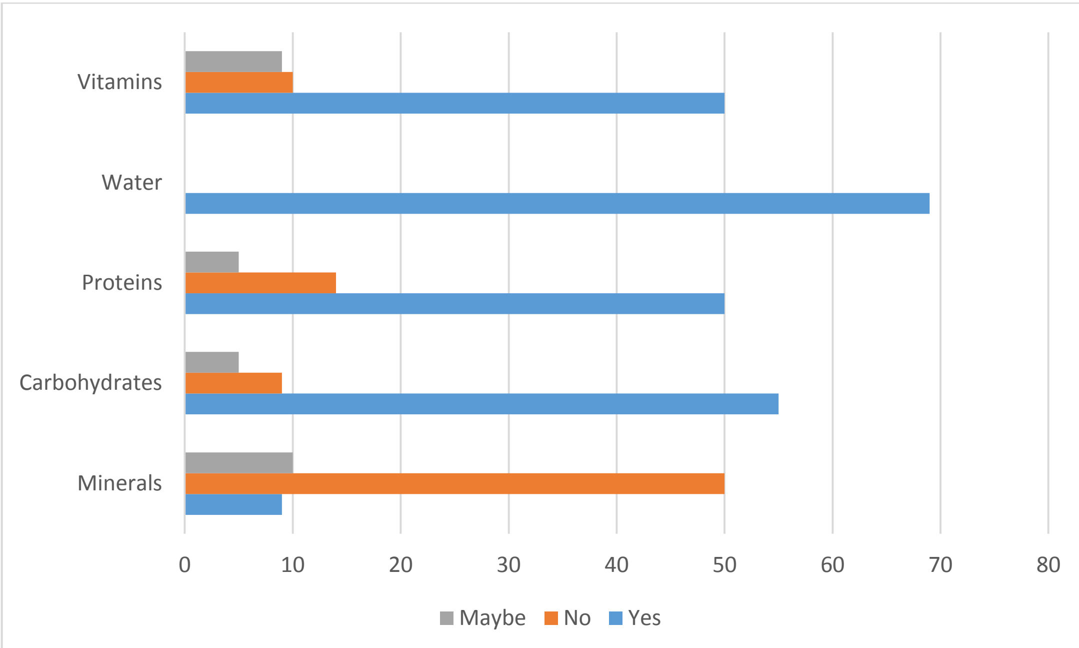


Figure 4.7Category of Nutrients Fed

4.2.8 Method of Preparing Infant Food

Figure 4.8 illustrates the respondents' ways of preparing infant food.

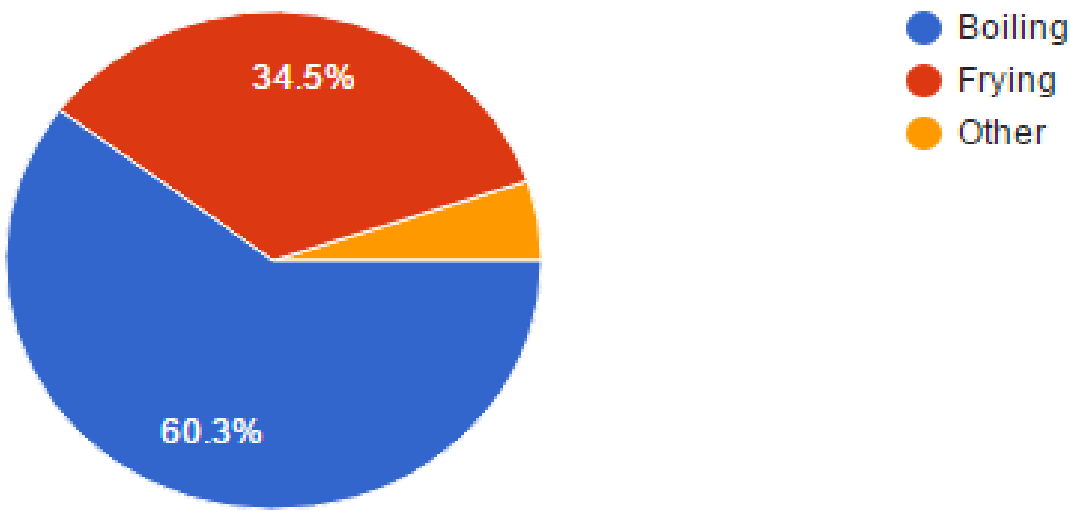


Figure 4.8 Method of preparing food

4.2.9 Usefulness of An Application for Generating Healthy Meals for Infants

Figure 4.9 illustrates the number of respondents who found it useful to have an application for generating healthy meals for infants

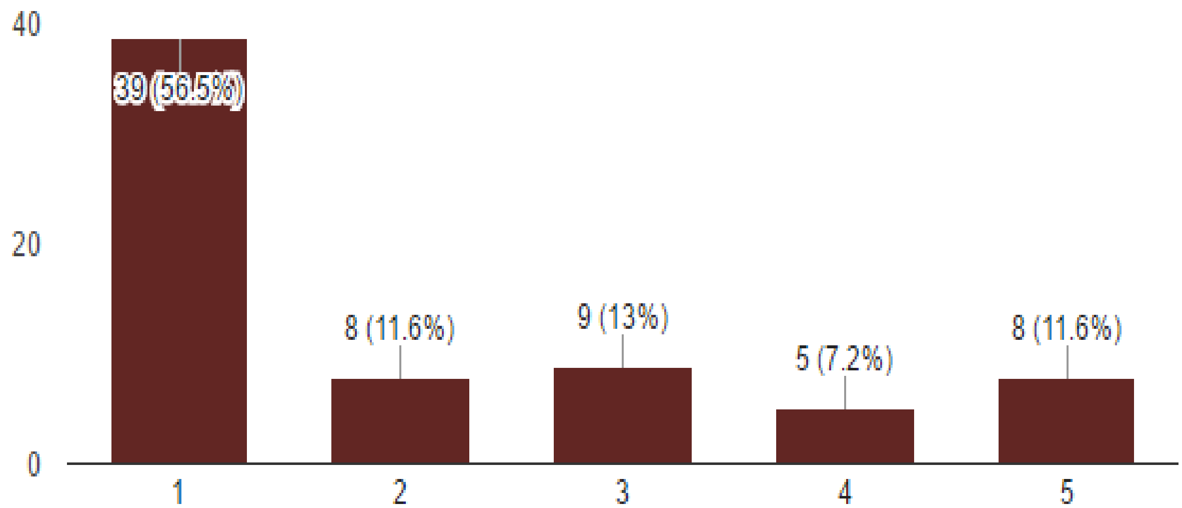


Figure 4.9 Mothers who think a model for measuring nutritional value of food is necessary

4.3 Requirements Gathering

Through the use of the questionnaire administered to mothers, the user requirements were obtained. A description of the service and features that should be addressed by the model for generating healthy meals for infants for infants can be divided into functional and non-functional requirements

4.3.1Functional Requirements

These are the basic processes and capabilities that the proposed application should be able to execute. This include, mother should be able to self-register herself and register her infant, the system should determine what age group the infant lies when the mother keys in the infant's age, the system should be able to advice what the recommended daily nutrients of an infant should be and generate a variety of daily meal schedules for the infant. The user should be able to give feedback on the application.

4.3.2 Nonfunctional Requirements

These are those qualities of the application that can be done without but are desired in order to make the application reliable, user friendly, interactive and easy to use. They include, security (the administrator should have authorized username and password to view the system), the system should be scalable to allow for future customization, the system should be easy to navigate, system should be available to use at any time.

4.4 System Architecture

Figure 4.10 is an illustration of the system architecture for the proposed model. It uses internet and web technology to deliver functionality. The architecture of this model is divided into four major components. These include the user interface, the internet/intranet/extranet access, application server and the database server. The user interface by which the user accesses the system is accessible using a web browser.

The system uses apache 2.* as the web server. The PHP functions are executed at this level. The implementations of the chosen algorithm takes place at this stage and rendered to the user interface using HTML and CSS. Search rules are also generated at this point in the knowledge acquisition facility.

Data storage is achieved using a robust relational database. Set functions here generate views from which the reports are retrieved from

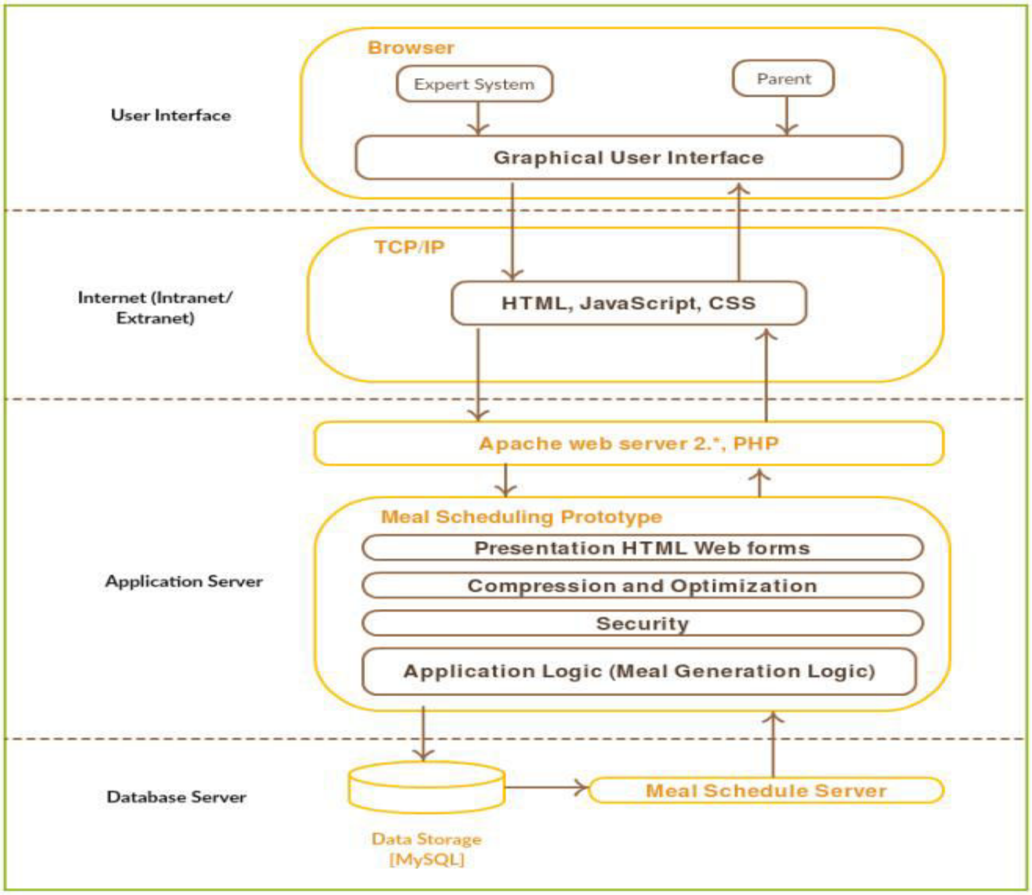


Figure 4.10 System Architecture

4.5 Use Case Modelling

The use case in the Figure 4.11 defines the infant nutrition model in relation to the world around it (depicted by the rectangle). The individuals (actors) involved with the system have been defined as well according to the roles they play in the system. The specific roles played by the actors (the use cases) appear within and around the system "rectangle" (such as update RDA and Register self). Finally, the relationships between and among the actors and the use cases have been defined (shown by the arrows).

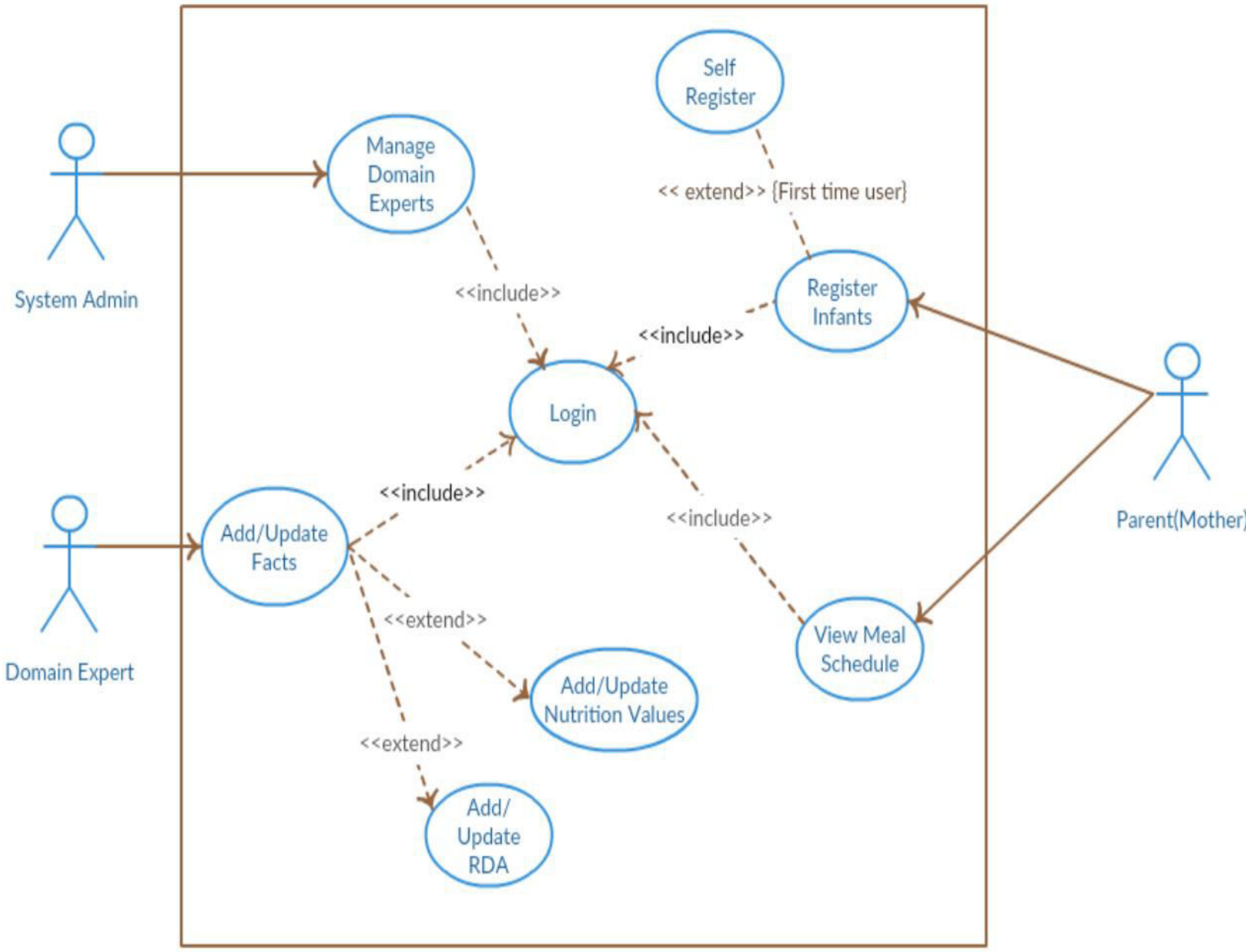


Figure 4.11Use Case Diagram

Use case diagrams played a big role in the system development as it helped to gather requirements of the system. The diagrammatic representation helps to get an outside view of the system to further aid in refinement of requirements. Factors influencing the system, be it external

Or internal are easily identified and interactions among the requirements and the actors is well modelled. Several main use cases were identified as described in the Table 4.1.

Table 4.1System Use Cases

Use Case	Actor	Description
1. Register Self	Mother	Register oneself into the system.
2. Domain Expert registration	System Administrator	Domain Expert registered
3. Add/update RDA& Nutrition values	Domain Expert	Maintain static data and system parameters such as RDA and food groups for the rules and knowledgebase entries for model, to generate healthy foods for infants
4. View generated meal schedule	Mother	View generated healthy food for feeding the infant
5. Manage Domain Experts	System Administrator	Administer domain expert role
6. Register Infants	Mother	Enter infant details for registration

4.6 Sequence Diagram

Figure 4.12 illustrates the sequence of activities that are followed to obtain this solution,

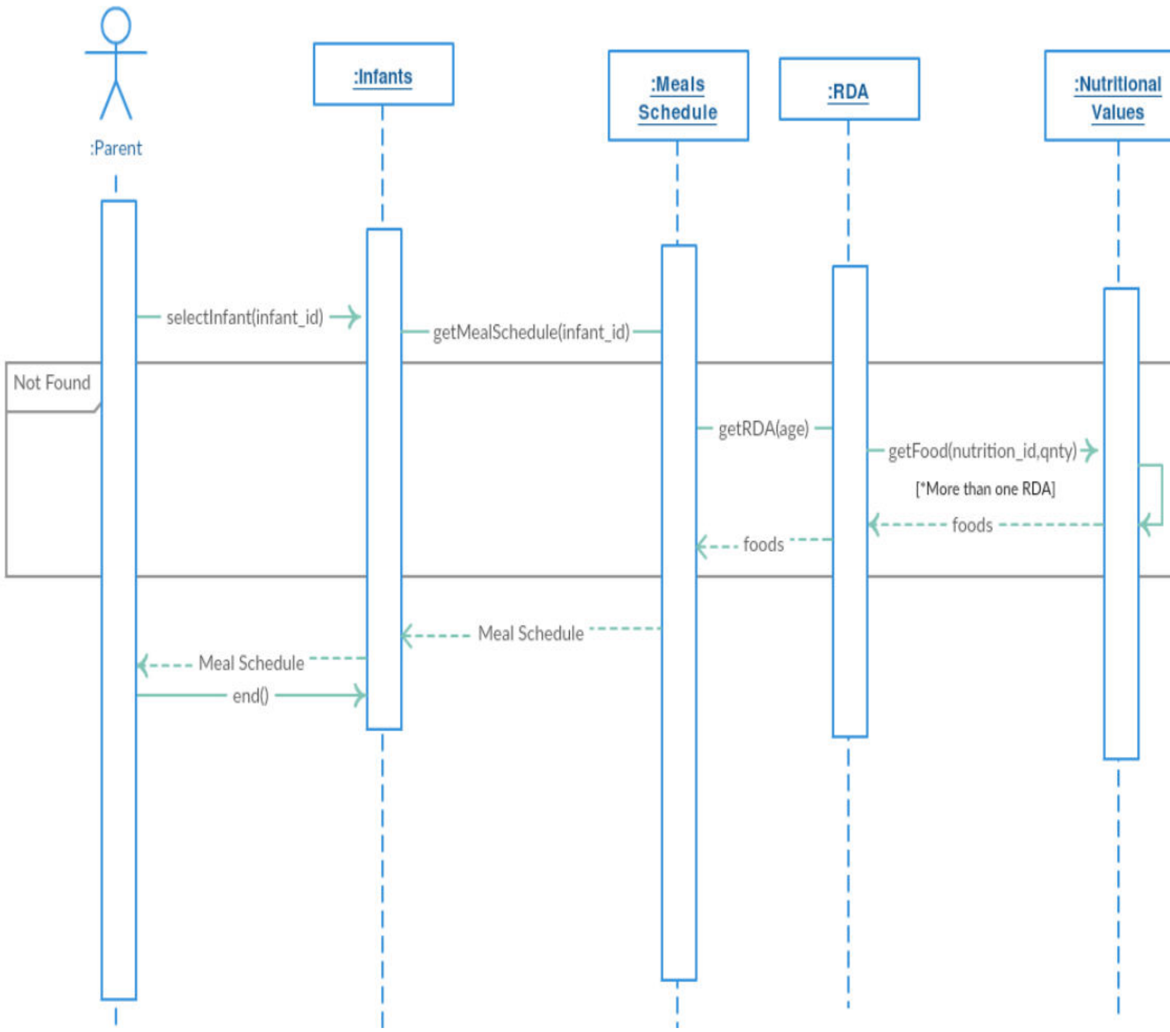


Figure 4.12 Sequence Diagram

The sequence diagram shows the object interactions during the process for measuring nutritional value of food for an infant. This includes the actor and the objects the actors interact with throughout the process of creating the meal schedule.

The parent (mother) initiates the process by logging in the infant. In the login phase infant personal data is entered. Age of the infant is used to determine the age stage of the infant. The RDA and nutrition data are used as input for determining the feeding requirements for the infant. Once this has been established, the system determines a meal schedule and displays it for the mother as feedback.

4.7 Context Diagram

The context diagram in Figure 4.13 shows the flow of data to and from the users to the application. There are mainly three users of the application users namely the parent (mother), system administrator and the domain expert. The mother provides an input (age) to the application and receives an output (meal schedule) from the system. The domain expert provides the expert knowledge on the healthy and balanced meal schedule based on the feeding requirement for the infant.

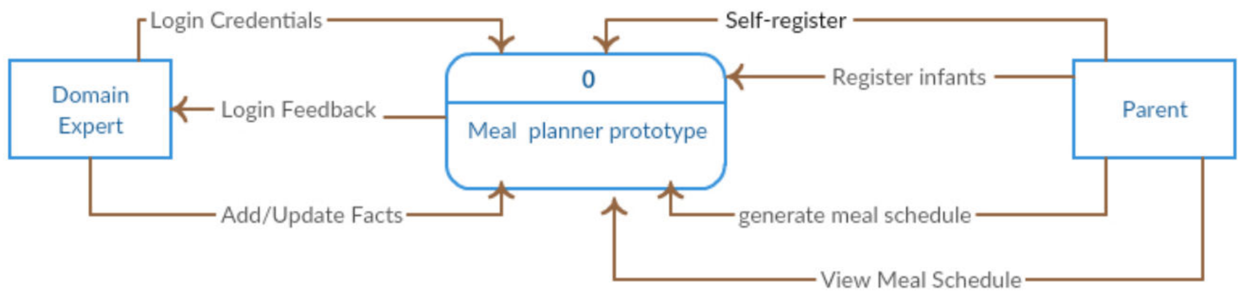


Figure 4.13 Context Diagram

4.8 Level 0 Data Flow Diagram

Figure 4.14 illustrates a Level 0 DFD diagram. It shows the various processes in the application, the data stores for storing facts and the entities that interact with the processes.

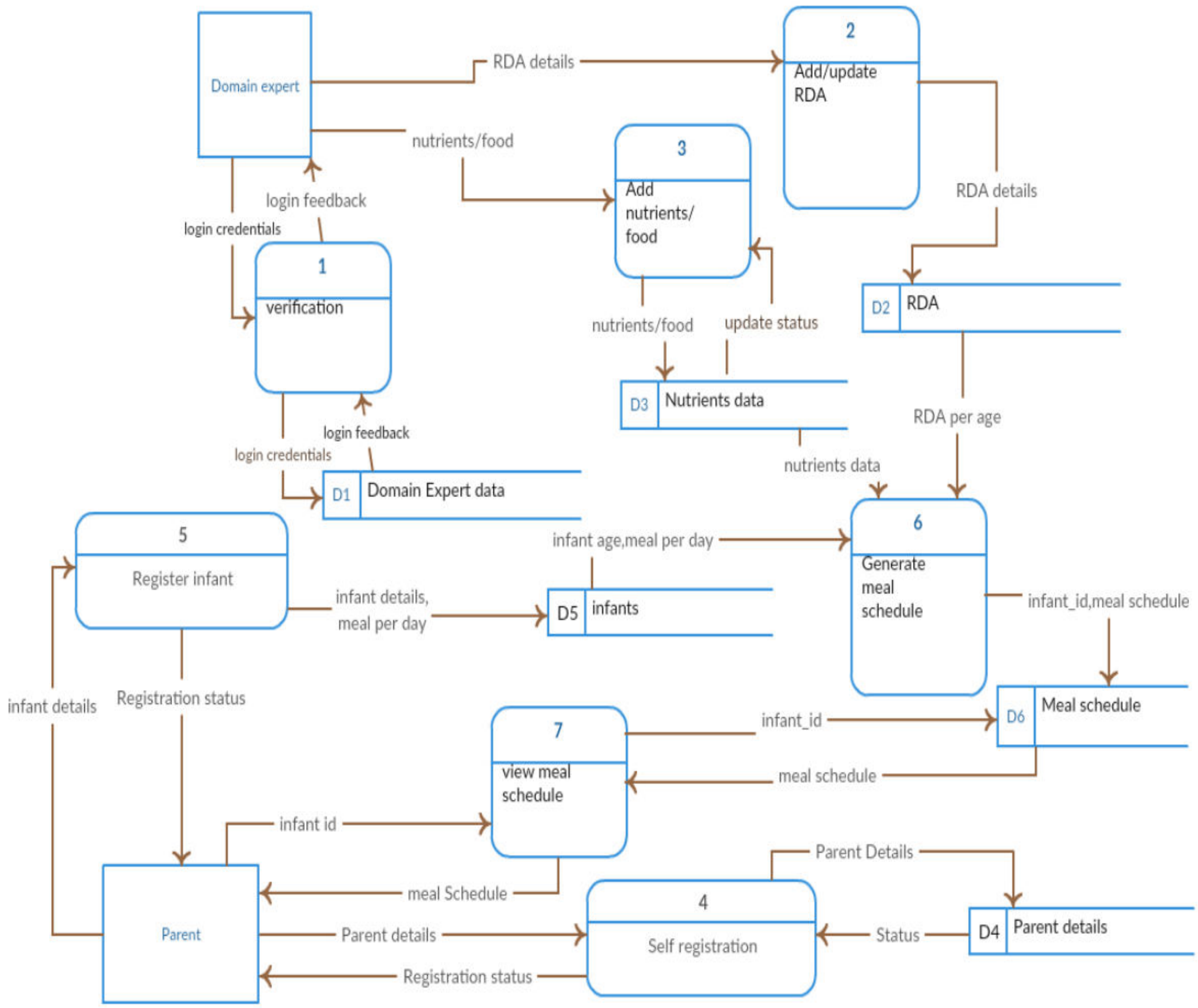


Figure 4.14 Level 0 DFD Diagram

4.9 Entity Relationship

An entity relationship model describes data in terms of entities, their attributes and relationships. (Riccardi, 2002). The entity relationship diagram represents and organizes data object in the database scheme without using the actual data. (Pagh, 2006)

The domain expert has the user id attribute as the primary key. The domain expert has a one to many relationship with the RDA entity. The domain expert is required to add/update the RDA entity constrantly.

The RDA entitiy has a one to many relationship with nutrients entity. The RDA entity which is represented as a table contains many facts on nutrients and each nutrient has an unique identifier called an Id.

The infant entity has Id, name and Age attributes. The infant Id is the primary key. An infant belongs to one parent(mother), the parent could have more than one infant at a time using the application but is registered only once. Therefore the parent entity has a one to many relationship with the infant entity

Food has a many to many relationship, they contain more than one nutrient and nutrients can be sourced from more than one food.

Figure 4.15 illustrates how the entities in the measuring nutrients model interact with each other

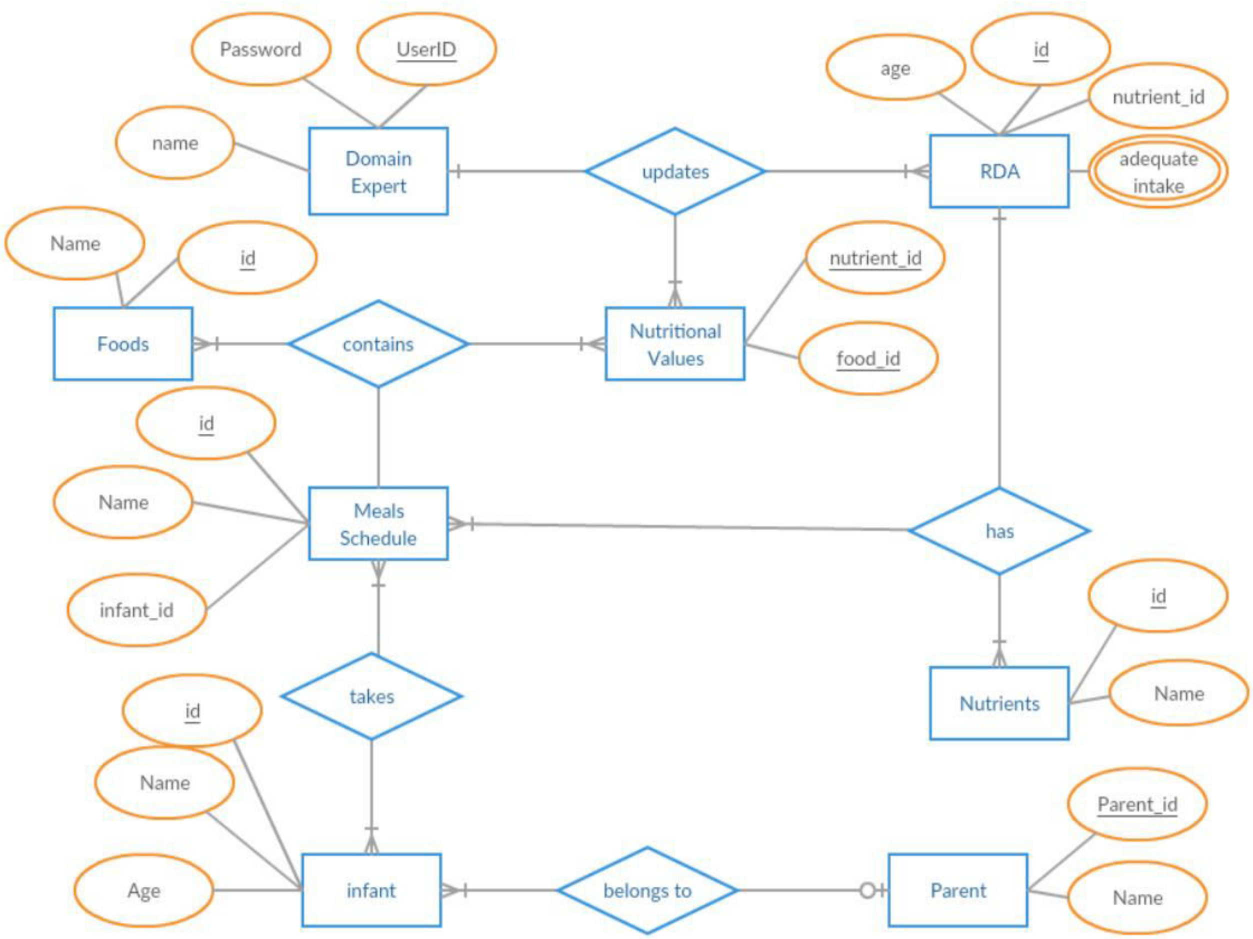


Figure 4.15 Entity Relationship Diagram

4.10 Class Diagram

The class diagram gives a representation of the attributes, methods, connections, interactions and inheritance of classes in an object oriented system. All concepts are characterized and described with a set of attributes such as the infant concept has name and age attributes.

It demonstrates the relations between concepts separated from the control of the model. The infant nutrition problem solving contains the calculating age stage of the infant, calculating daily recommended nutrients for an infant and determining meal schedule. Figure 4.16 is an illustration of the class diagram.

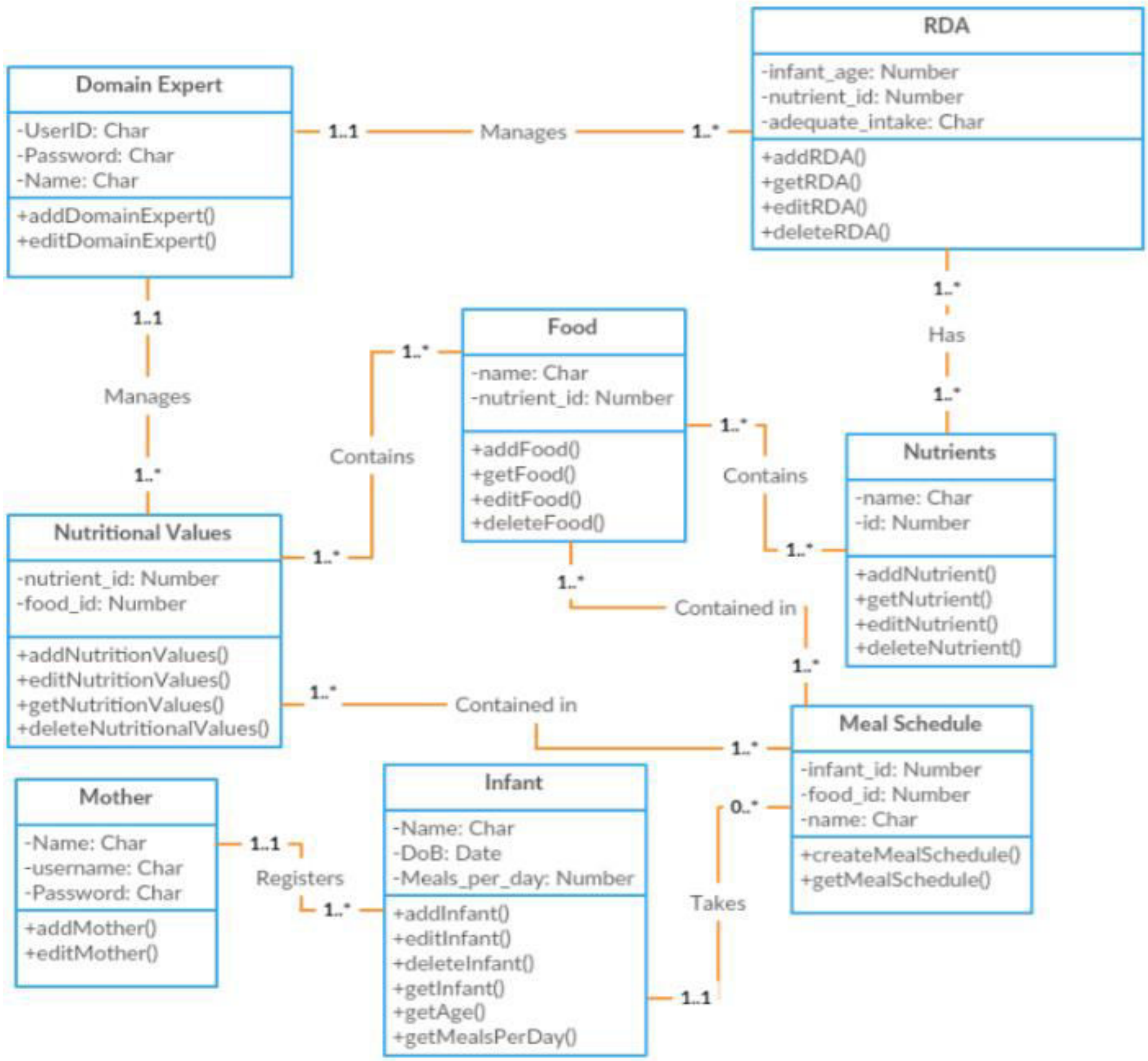


Figure 4.16 Class Diagram

Chapter 5 : System Implementation

5.1 Overview

This chapter focusses on the implementation and testing of the proposed solution. The development languages used to create the model are PHP, CSS, JavaScript, HTML and MySQL database. PHP was used to execute the logic. PHP and JavaScript were used for validation and for ensuring the system is dynamic. MySQL was used to store the data and the knowledgebase generated. Users can access the model using internet browsers. The testing of the application was to establish the level of functionality and usability of the model.

5.2 Program flow

After the mother successfully registers the infant and enters the birthdate of the infant, the system calculates the age of the infant. This classifies the infant in a certain age stage, each age stage has its nutrition requirements. The next step is determining the feeding requirements for a specific infant according to the determined age stage. The main feeding requirements are driven by the defined required nutrients per day as obtained from the RDA table. Once the feeding requirement has been obtained, the food groups which provide these needed nutrients are determined from the nutrition database and used to produce a meal schedule for the child. Once the model has determined a meals schedule for the infant it displays the meals schedule to the mother. A summary of this processes is illustrated in Figure 5.1.

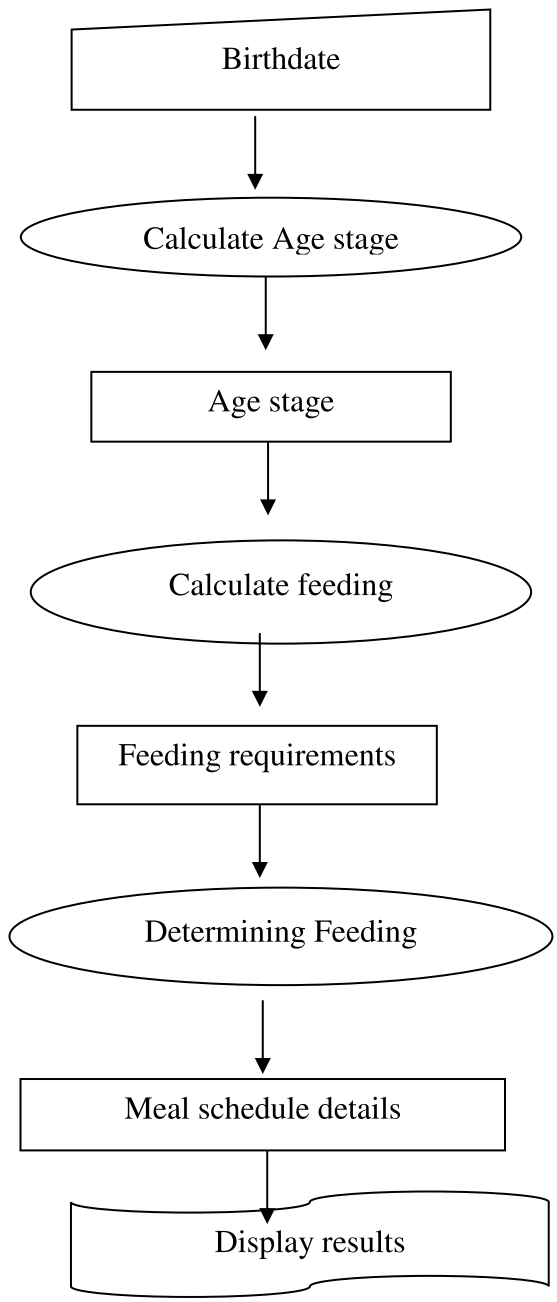


Figure 5.1 Program Flow

5.3 Sample Forms Used

To provide interaction between the user and the model, several interfaces were built. Each task was represented by its own interface. These tasks being, self registration of the parent, registering of the infant.

5.3.1 Self Registration of Parent.

This was a one time registration of the mother who enters her name and email address to enable her to register and login her infant thereafter. Figure 5.4 is an illustration of the interface

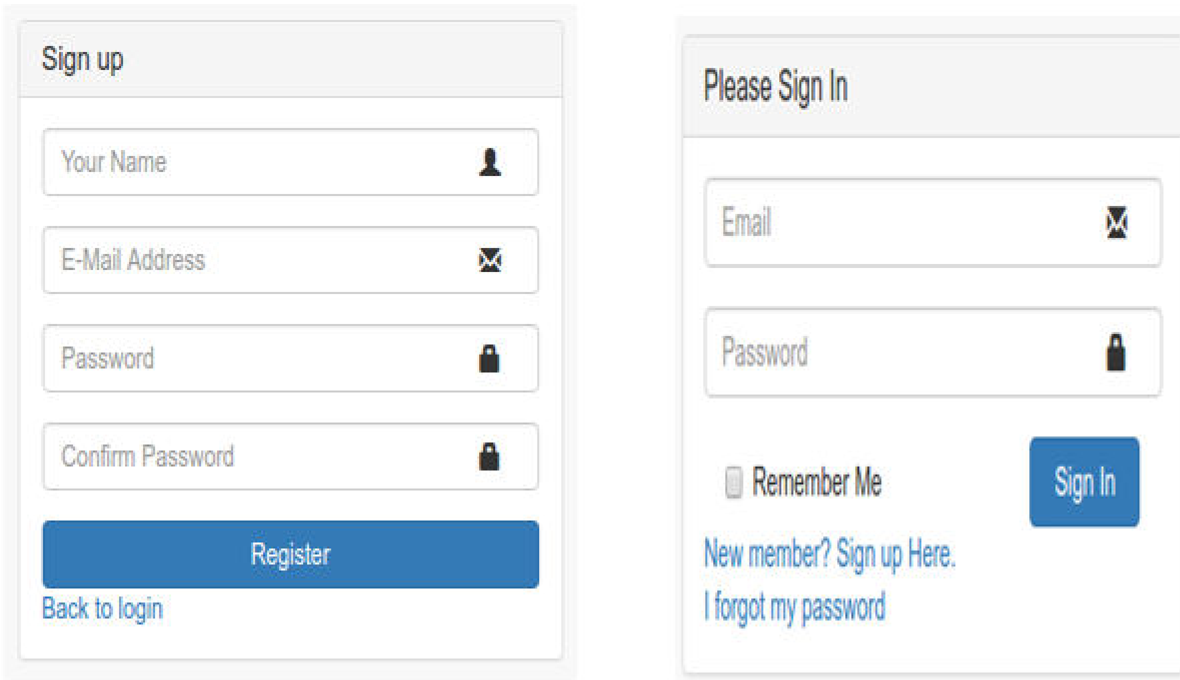


Figure 5.2 Mother Self-Registration Interface

5.3.2 Registrering of infant

Once the mother has self registered, she can enter the personal data of the infant in the " infant interface" . Among the bio- data captured is name of infant, date of birth and required meals per day. From this interface, the mother is able to generate a new meal schedule or view an old meal schedule. Figure 5.5 is an illustration of the infant registration details

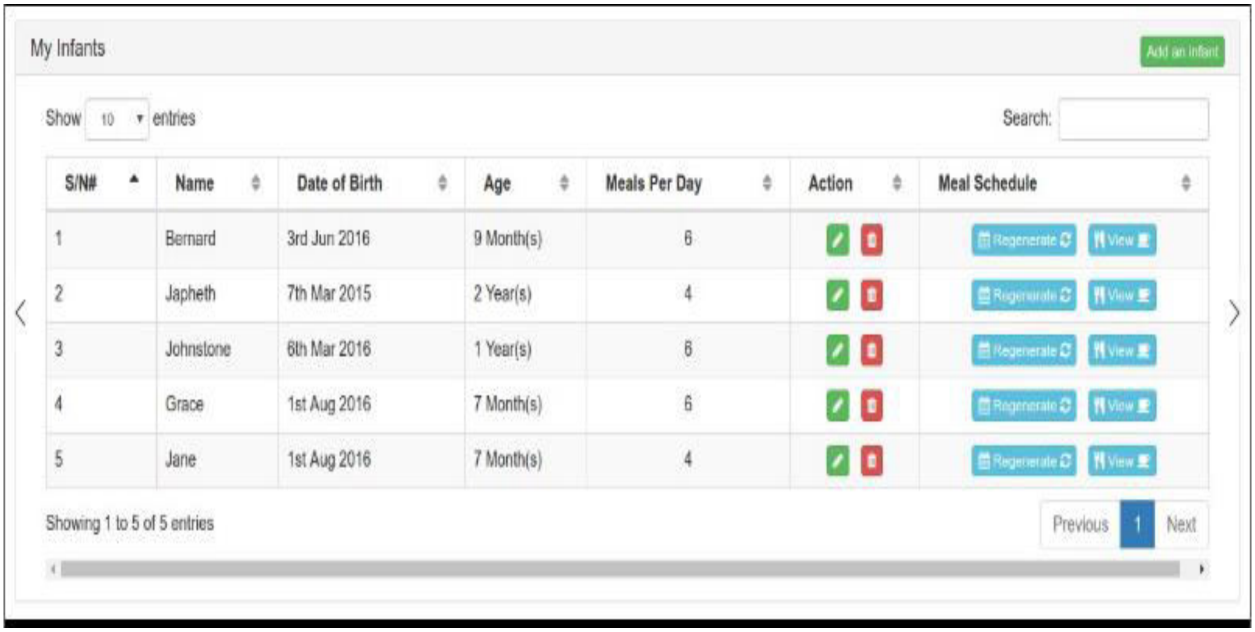
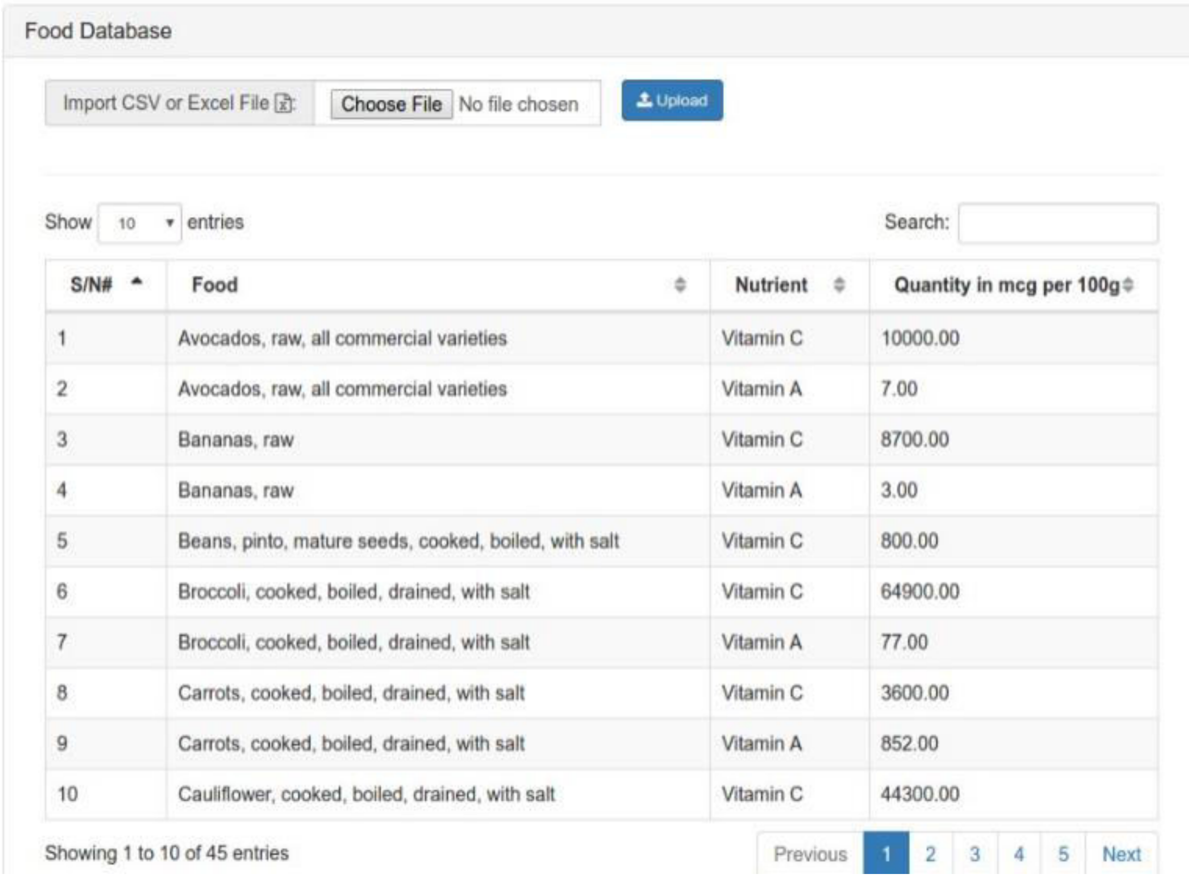


Figure 5.3 Infant Registration

5.3.3 Food Unit Nutrients

Figure 5.6 is an illustration of the food unit nutrients which is represented as a table that acts as an input for the expert sytem. The table contains food unit nutrients with various types of nutrient types. Computations are done using rules with RDA input to determine a meal schedule comprising of the needed daily nutrient intake for an infant. Each food unit nutrient was measured per 100g and since heat alters the nutritional value of food, the mode of cooking food was put into consideration. To measure the, the mother will require to use the the 100g cup that has been marked with measurements.



Food Database

Import CSV or Excel File | Choose File No file chosen | Upload

Show 10 entries   Search:

S/N#	Food	Nutrient	Quantity in mcg per 100g
1	Avocados, raw, all commercial varieties	Vitamin C	10000.00
2	Avocados, raw, all commercial varieties	Vitamin A	7.00
3	Bananas, raw	Vitamin C	8700.00
4	Bananas, raw	Vitamin A	3.00
5	Beans, pinto, mature seeds, cooked, boiled, with salt	Vitamin C	800.00
6	Broccoli, cooked, boiled, drained, with salt	Vitamin C	64900.00
7	Broccoli, cooked, boiled, drained, with salt	Vitamin A	77.00
8	Carrots, cooked, boiled, drained, with salt	Vitamin C	3600.00
9	Carrots, cooked, boiled, drained, with salt	Vitamin A	852.00
10	Cauliflower, cooked, boiled, drained, with salt	Vitamin C	44300.00

Showing 1 to 10 of 45 entries   Previous 1 2 3 4 5 Next

Figure 5.4 Food Unit Nutrients

5.3.4 Addition of RDA

This interface provided a convenient way to add/ update RDA values which are used to calculate the needed daily nutrients for an infant. The domain expert enters the new RDA values of the required amount of nutrients for each age and clicks “Add RDA”. The model validates the data to ensure it is in the right format before it is entered in the database. A list of entered RDA values are displayed. The key attributes displayed include age, nutrient Id, and the Recommended Daily Allowance value(RDA), to edit RDA values the administrator makes the changes and clicks on the “save changes” button. Figure 5.7 is an illustration of add/edit RDA values

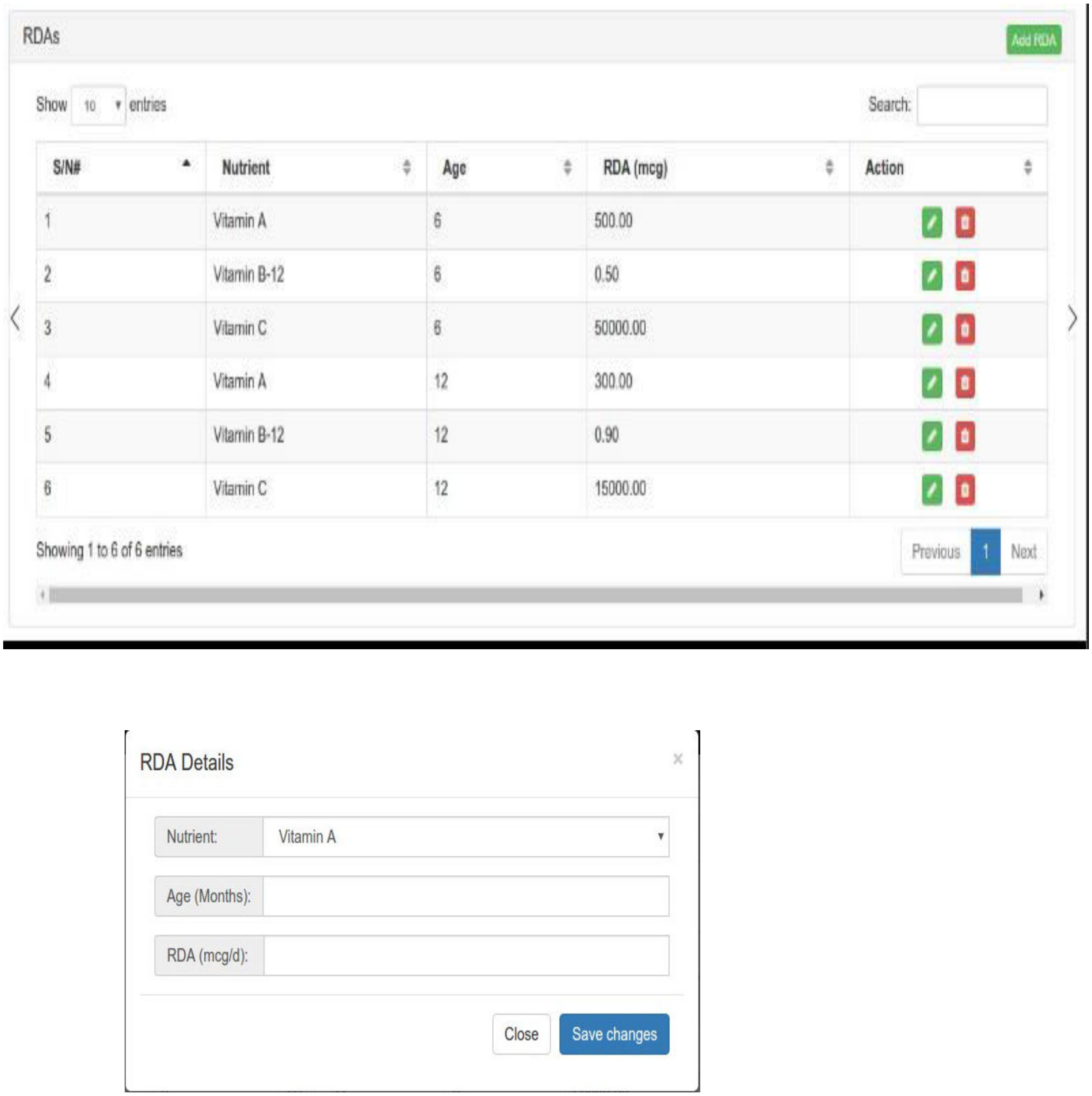


Figure 5.5 Add/Update RDA Details

5.4 Model Validation

To ensure the model does what it is designed to do, a number of validations have been built in. Users are validated upon login and only registered users with valid credentials are granted access to the model. Error messages are displayed inorder to inform the user of what is wrong with the entry and instruct them on what to do. Among the fields validated included Name of infant, age, and meals scheduled. Leaving any of the required fields would prompt the user to enter them as shown in Figure 5.8

Figure 5.6 Model Validation (Infant name, Date of Birth, Meals per Day Missing)

Whenever some of the RDA detailed were omitted such as age or Recommend Nutrient intake an error was thrown for the administrator to enter the missing data. Figure 5.9 illustrates the validation of RDA details.

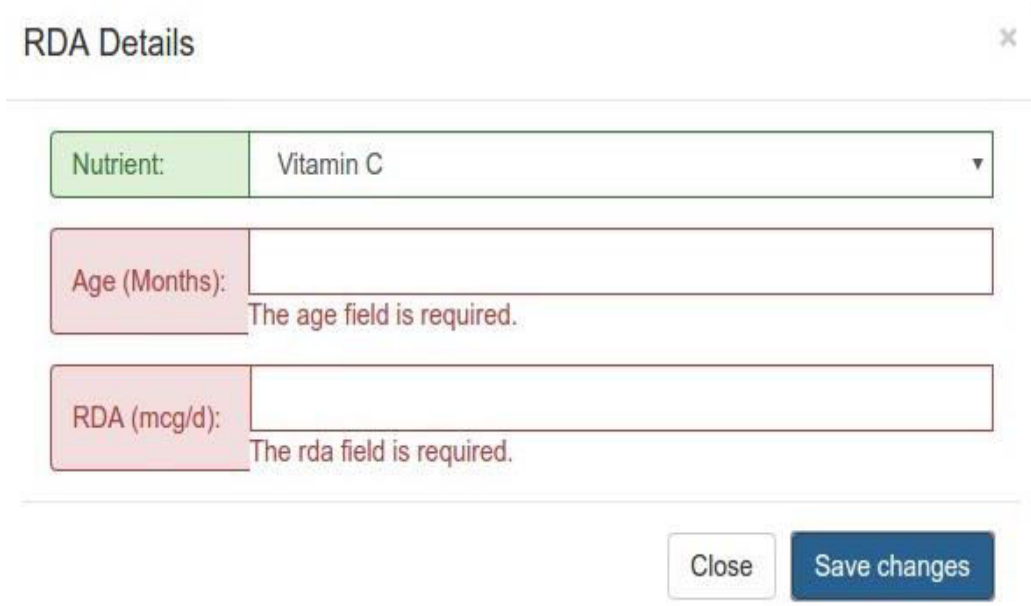


Figure 5.7 Model Validation for RDA Details Entry (Age and RDA Values Missing)

5.5 Model Testing

The objective of the model testing is to assess the effictiveness of the model in generating healthy meals for an infant . Testing is done to verify and validate that a program, subsytem or application performs the functions for which it has been designed. Testing the model was done as illustrated on individual use cases. This is illustrated in Table 5.1

Table 5.1 Test Cases

ID	Case	Expected Outcomes	Comments
1	Register Self and Login		
1.1	Launch the application from the web browser	Application Launched successfully	Pass
1.2	Click on “register” button	“Register self” Activity displayed	Pass
1.3	Submit without entering details	Error displayed	Pass
1.4	Enter username, password, password confirmation and submit	Record saved successfully	Pass
1.5	Login to the system by supplying the username and password	Login successful	Pass
2	Register Infant		
2.1	Select “Infant details” on the menu	“Infant details” activity displayed	Pass
2.2	Submit without entering any details	Error displayed	Pass
2.3	Enter infant name, date of birth and meals per day	Record saved successfully	Pass
3	Entry and Updating of RDA details		
3.1	Select “RDA details” from the menu	“RDA details” activity displayed	Pass
3.2	Submit without entering any details	Error displayed	Pass

3.3	Enter Age and RDA	Record saved successfully	Pass
4	View Meal Schedules		
	Access the “Meal Schedule” module	Menu accessed successfully	Pass

5.6 System Parameters and Static Maintenance

Various parameters and static maintenances can be performed. This is to ensure the system remains dynamic and is able to adopt to changes that might occur without consulting the developers. This maintenances include “if ….then” rules in the knowledge base, RDA details, nutrition data and infant details in the facts database.

5.7 Usability Testing Results

5.7.1 Respondents Who Logged in Successfully

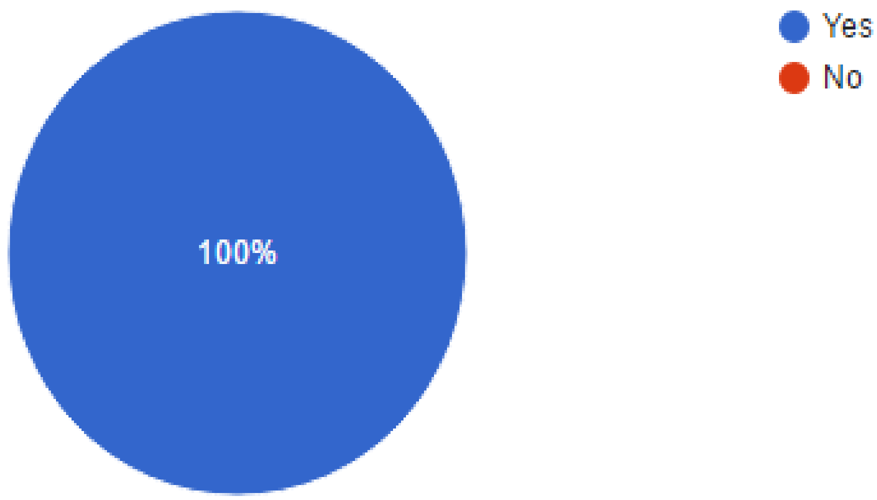


Figure 5.8 Respondents who successfully logged in the infant

Respondents were required to self-register at the start of using the system. Figure 5.10 shows that all the respondents successfully self-registered to login to the model.

5.7.2 Attributes Rating for The Model

Out of the 10 respondents who participated in the model usability testing, 4 rated navigability good and 6 rated very good. For easy to learn attribute, 4 rated good, 3 very good and 3 excellent. For user friendly attribute 4 rated good, 4 very good, 2 excellent for responsiveness 4 rated good, 4very good,, 2 excellent for useful and satisfying 2 rated good, 6 rated very good, 2 rated excellent. This is illustrated in Figure 5.11

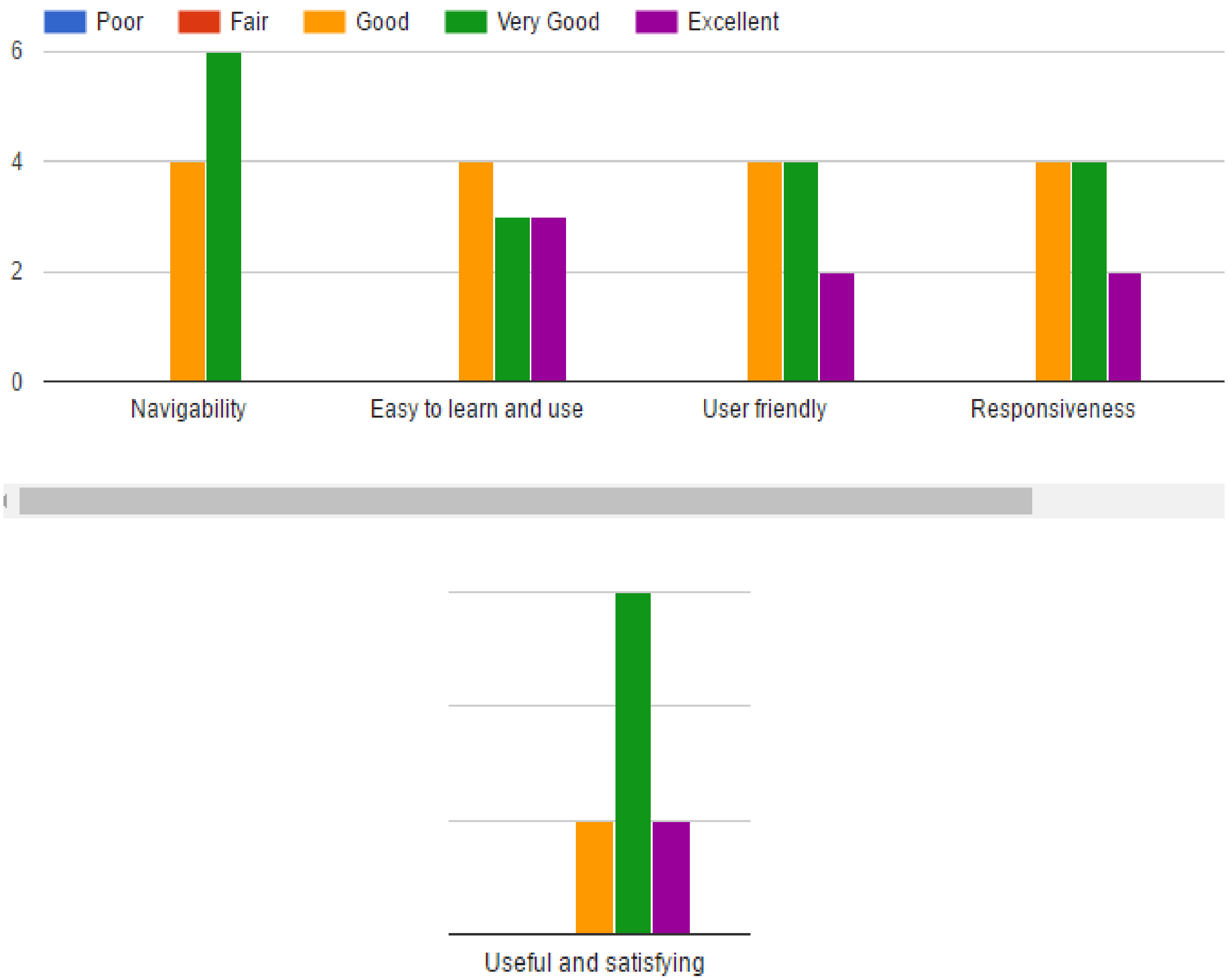


Figure 5.9 The model Attributes Rating

5.7.3 Respondents Who Received a Meal Schedule

At the request of the respondents, the model was able to generate a meal schedule for the infant to all respondents as illustrated in Figure 5.12.

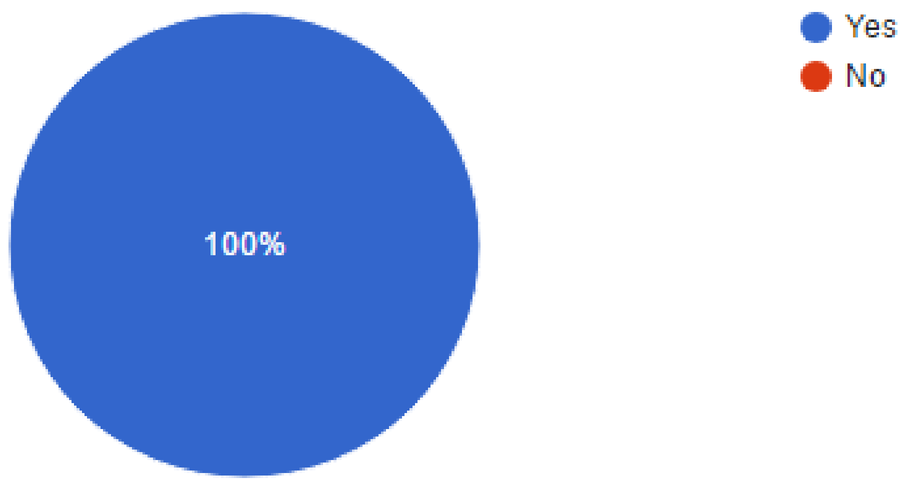


Figure 5.10 Respondents Who Received a Meal Schedule

5.7.4 Comments and Recommendations for The Model

Respondents gave the below comments and recommendations for the model

very useful
interesting tool
useful for first time moms
very useful, expand for largescale
relevant for good health of infant
useful in curbing malnutrition
should be made mandatory for parents
makes meal preparing easy and quick
add food options

Figure 5.11Comments and Suggestions for the model

Chapter 6 : Discussion

6.1 Introduction

This chapter presents a discussion of how the researcher addressed the research objectives of the study and whether all objectives were met. As such, it analyzes the findings of the study in relation to research objectives and their conformity with the literature review. The study was built on five objectives, with the development of the model and testing being the core objectives.

6.2 Meeting Nutrition Needs of Infants

The study established the nutritional requirements of an infant as reviewed in section 2.4 of the literature review. We focused our research on infants of ages 0 to 36 months. For purposes of this research, age was the primary determinant that was used for determining the nutrient requirements of an infant. The RDA table from the Institute of Medicine has been used as the material from which we reference the recommended daily allowance to feed an infant. Using this data and that from the nutrition databases a knowledge base was created for scheduling a recommended meal for the infant. The researcher administered the use of online questionnaires which revealed that the majority of mothers and caregivers are not aware of the recommended nutrients needed by an infant, only 36 % of the respondents were sure that they met the nutrient requirements. 35.6 % of the respondents said they acquired nutrition advice from the internet and 47.5% of the respondents indicated they experienced a challenge with the information acquired as they found it ambiguous and unclear. The model was therefore considered a suitable option for recommending healthy meals for infants compared to other methods such as manually searching on the Internet, or hiring a nutritionist to offer nutrition advice. These other options were considered time-consuming and tedious and others expensive. The model used RDA data and Age of infant, and nutrition data from USDA nutrition database as input. Calculations in the form of rules were used to determine the feeding requirements of an infant and create a meal schedule that recommended healthy and balanced meals for an infant.

6.3 Review of Methods Used To Obtain Nutrition Advice

The second objective was to determine the methods and tools used to determine nutritional value of food. From the study findings, majority of the respondents said they receive nutrition advice from the internet, others nutritionist while others get from the hospital during post-natal visits.

The study findings also shows that respondents face challenges such as ambiguous and unclear information, forgetting what quantities they feed the infant and others mentioned that the information was not readily available.

6.4 Determining Data and Information Requirements for the Model

From the online questionnaire commonly fed foods were established and the mode of cooking used was also established. This information as indicated in chapter 2 is important in determining the nutritional value of food. One type of food cooked either by frying or boiling will result in different nutritional value. Majority of the respondents said they choose to boil infant food.

6.5 Developing a Model for Generating healthy meals for infants

The fourth objective was to develop a model for generating healthy meals for infants. Research findings show that the respondents find it necessary to develop a model that will measure nutritional value of food and recommend a health meal for infants. The model removes the burden of having to remember what the mother feeds the infant while trying to assess the nutritional value of the food or dealing with ambiguous and unclear information. The respondent does not have to perform any tedious activity of searching the internet for advice. The model provides a quick and automated way to get healthy meal recommendations.

6.6 Testing the Model

The last objective was to test the model. The usability questionnaire in Appendix B was used to test the developed model. All the respondents who participated in the usability testing did not experience problems logging in the infant. Out of the 10 respondents who participated in the application usability testing 4 rated it good and 6 rated it very good

Chapter 7 : Conclusions and Recommendations

7.1Introduction

Infancy is the period in which undernutrition has the most severe consequences than at any other stage of life since most of the effects of undernutrition are irreversible at this stage. Infant undernutrition is common for many infants in sub-Sahara as a result of lack of information and poor diets. A model for generating healthy meals for infants was proposed to recommend healthy and balanced meals for infants. This chapter gives the conclusions, recommendations and future work as observed by the researcher.

7.2 Conclusion

The study reveals that most mothers have a challenge accessing nutrition information and feed their infants without the knowledge of the needed nutrients. Key of these challenges they face include undeveloped structural support systems that fail to focus on the unique nutritional needs of an infant. Using the data and information gathered in section 2.4 led to the development of the nutrition model for infants based on a rule-based expert algorithm. The researcher determined that to serve the nutritional needs of an infant, age of the infant and Recommended Daily Allowance (RDA) were the inputs needed to determine the feeding requirements of the infant.
The model acquired the age of the infant from the mother, and used the Recommended Daily Allowance (RDA) obtained from Institute of Medicine (IOM), which gives a recommendation of the needed nutrients an infant needs to take in a day

Nutrition mapping was performed to realize the food groups that would supply all the needed nutrients as recommended by the RDA. Next the nutrient values were obtained from the nutrition database. The Steps toward calculating the nutrient value of a meal entails determining the weight in grams of each ingredient, determining nutrients in the total meal by summing nutrient values for each ingredient of the meal and converting the nutrient values for the total meal to the 100-gram basis. Having obtained the feeding requirements and determined the food groups that would supply the needed nutrients. A meal schedule was created through which the infant would meet all the needed nutrients in a day.

Agile software methodology was used which enabled more frequent release with subsequent user feedback which led to the development of a useable and reliable system. The usability testing was performed and the respondents found it useful and satisfying. If this model is developed fully into an application it will allow for the overall health improvement of the infant, it will make mothers have an easier time meeting the needed nutrient needs of an infant.

7.3 Recommendations

The model was of great importance to the respondents due to its simplicity in use and that it wasn't tedious in delivering the information needed. However the researcher noted that there was more that could be done in the area of nutrition for infants and gave the following recommendations.

i. In order to increase the adoption of the nutrition model, awareness should be conducted to enable users know about the model.
ii. Due to the realization of the importance of the tool to the users, the model could be advanced to a fully functional application by collaborating with county government for them to adopt some technology at the hospitals while imparting nutrition knowledge to mothers.
iii. Vary, the databases of food to accommodate more user preferences.
iv. The researcher recommends an addition to the knowledge database by including more specialized nutrition information such as RDA for infants who are overweight and underweight.
v. Upgrade continuously to accept the needs of users or experts

7.4 Suggestions for Future Work

i. The model can be extended to accommodate forums by nutrition experts and mothers so that the expert can give expert information on various issues that the mothers could raise.
ii. The model can be used to support local languages to accommodate mothers of various backgrounds. The model can be built to support speech to text

References

Ackers, K., Bash, N., & Routledge, G. (2016, September 03). Artificial Intelligence Meets Nutrition. Retrieved from http://www.thefoodrush.com/blog/artificial-intelligence-meets-nutrition/

Agapito G., C. B., Guzzi P. H, H. P., Cannataro M, M., Simeoni M, M., & Care´ I, L. I. (2016). DIETOS: A Recommender System for adaptive adaptive diet monitoring and personalized food suggestion. *IEEE*.

American Academy of Pediatrics. (2016). Page. *Pediatrics*, *137*(Supplement 2), 137S2-137S2.

Årsand, E., Tufano, J. T., Ralston, J. D., & Hjortdahl, P. (2008). Designing Mobile Dietary Management Support Technologies for People with Diabetes. *Journal of Telemedicine and Telecare, 14(7)*, 329-332.

Becker, G. S. (1965). The Theory of Allocation of Time. *The Economic Journal*.

Belatrix. (2015). *Functional Testing Best Practises.* Retrieved from Belatrix Software: https://www.belatrixsf.com/

Bognar, A., & Piekarski, J. (2000). Guidelines for Recipe Information and Calculation of Nutrient Composition of Prepared Foods. *Elsevier*.

Boushey, C. J., Kerr, D. A., Wright, J., Lutes, K. D., Ebert, D. S., & Delp, E. J. (2009). Use of Technology in Children's Dietary Assessment. *European Journal of Clinical Nutrition, 63*, S50-S57.

Bowman, S. A., Gortmaker, S. L., Ebbeling, C. B., Pereira, M. A., & Ludwig, D. S. (2004). Effects of Fast-Food Consumption on Energy Intake and Diet Quality Among Children in a National Household Survey. *Pediatrics, 113(1),* , 112-118.

Burke, B. S. (1947). The Dietary History as a Tool in Research . *Journal of the American*

Cagiltay, N. E., Tokdemir, G., Kilic, O., & Topalli, D. (2013). Performing and analyzing non-formal inspections of entity relationship diagram (ERD). *Journal of Systems and Software*, *86*(8), 2184-2195.

Charles, P., Grothoff, C., Saraswat, V., Donawa, C., Kielstra, A., Ebcioglu, K., ... & Sarkar, V. (2005, October). X10: an object-oriented approach to non-uniform cluster computing. In *Acm Sigplan Notices* (Vol. 40, No. 10, pp. 519-538). ACM.

Dandyal, S. D. (2004). How Personal Factors, Including Culture and Ethnicity, Affecting the Choice and Selection of Food We make. *The Internet Journal of Third World Medicine,*

Dietary Guidelines. (2010). Retrieved from https://health.gov/dietaryguidelines/2010/

Dymova, L., Sevastianov, P., & Bartosiewicz, P. (2010). A new approach to the rule-base evidential reasoning: Stock trading expert system application. *Expert Systems with Applications, 37(8)*, 5564-5576.

Food for Health: Dietary Guidelines for Children and Adolescents in Australia. (2009). Retrieved from http://www.health.gov.au/internet/publications/publishing.nsf/Content/gug-family-toc~gug-family-guidelines

Ferguson, E. L., Gadowsky, S. L., Huddle, J. M., Cullinan, T. R., Lehrfeld, J., & Gibson, R. S. (1995). An Interactive 24-h Recall Technique for Assessing the Adequacy of Trace Mineral Intakes of Rural Malawian Women; Its Advantages and Limitations. *European Journal of Clinical Nutrition, 49(8)*, 565-578.

Gewa, C. A., Murphy, S. P., & Neumann, C. G. (2009). A Comparison of Weighed and Recalled Intakes for Schoolchildren and Mothers in Rural Kenya. *Public Health Nutrition, 12(08)*, 1197-1204.

Gibson, R. S. (2005). *Principles of Nutritional Assessment* . Oxford University Press.

Government of Kenya (GOK). (2007). *Kenya Vision 2030: A Competitive and Prosperous Kenya.* Nairobi: Government Printer.

Gupta, S., & Ritika Singhal, R. (2013). Fundamentals and Characteristics of an Expert System. *International Journal on Recent and Innovation Trends in Computing and Communication* .

Gwet, K. L. (2014). *Handbook of inter-rater reliability: The definitive guide to measuring the extent of agreement among raters. Advanced Analytics, LLC.*

Hazman, M., & Idrees , A. M. (2015). A Healthy Nutrition Expert System for Children. *IEEE*.

Hong, S. M., Cho, J. Y., Lee, J. H., Kim, G., & Kim, M. C. (2008). NutriSonic web expert system for meal management and nutrition counseling with nutrient time-series analysis, e-food exchange and easy data transition. *Nutrition research and practice, 2(2)*, 121-129.

Hsieh, H.S (2005). Three approaches to qualitative content analysis. Retrieved from https://www.nchi.nlm.nih.gov/pubmed/16204405

Huda, M., Arya, Y. D. S., & Khan, M. H. (2014). Measuring Testability of Object Oriented Design: A Systematic Review. *International Journal of Scientific Engineering and Technology (IJSET)*, *3*, 1313-1319.

International Medical Corps. (2015). Retrieved from https://internationalmedicalcorps.org/who-we-are

IOM (Institute of Medicine) . (2000). *Dietary Reference Intakes: Applications in Dietary Assessment.* Washington, DC: National Academy Press.

IOM. (2002). The Evidence for the Effectiveness of Medical Nutrition Therapy in Nutrient Intakes. *Nutritional Value, 25(3)*, 608-613.

Jelliffe, D. B., & Jelliffe, E. P. (1978). Human Milk in the Modern World . *British Medical Journal, 2(6151)*, 1573.

KDHS. (2014). Nutrition of Children and Women: Kenya Demographic and Health Survey 2014. *The DHS Program*, 157-180.

Kenya National Bureau of Statistics. (2010). *The 2009 Population and Housing Census.* Nairobi: KNBS.

Kigutha, H. N. (1997). Assessment of Dietary Intake in Rural Communities in Africa: Experiences in Kenya. *The American Journal of Clinical Nutrition, 65(4)*, 1168S-1172S.

Kothari, C. R. (2004). *Research Methodology Methods & Techniques.* India: New Age International (P) Limited, Publishers.

Levin, W. S. (2013). *Parenting Without Fear: The Foundation for Raising Balanced Children in a Healing World.* Hillcrest Publishing Group.

Liao, S. H. (2005). Expert system methodologies and applications - A decade review from 1995 to 2004. *Expert systems with applications, 28(1)*, 93-103.

Lioret, S., McNaughton, S. A., Spence, A. C., Crawford, D., & Campbell, K. J. (2013). Tracking of dietary intakes in early childhood: The Melbourne InFANT Program. *European journal of clinical nutrition, 67(3)*, 275-281.

MacIntyre, U. E., Venter, C. S., & Vorster, H. H. (2001). A Culture-Sensitive Quantitative Food Frequency Questionnaire Used in an African Population: 2. Relative Validation by 7-day Weighed Records and Biomarkers. *Public Health Nutrition, 4(01)*, 63-71.

Mahan, L. K. (2004). *Krause's Food, Nutrition, & Diet Therapy.*

Mashburn, A. J., Meyer, J. P., Allen, J. P., & Pianta, R. C. (2014). The effect of observation length and presentation order on the reliability and validity of an observational measure of teaching quality. *Educational and Psychological Measurement, 74(3)*, 400-422.

Matthews, R. H. (1988). *Recipe calculations vs analytical values.*

Nishida, C., Uauy, R., Kumanyika, S., & Shetty, P. (2004). The Joint WHO/FAO Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases: Process, Product and Policy Implications. *Public Health Nutrition, 7(1a)*, 245-250.

Ohl, C. A., & Tapsell, S. (2000). Flooding and Human Health: The Dangers Posed are not always Obvious. *British Medical Journal, 321(7270)*, 1167-1167.

O'neil, C. E., Nicklas, T. A., Keast, D. R., & Fulgoni III, V. L. (2014). Ethnic disparities among food sources of energy and nutrients of public health concern and nutrients to limit in adults in the United States: NHANES 2003–2006. *Food & nutrition research*, 58.

Pagh, R. (2006). *The entity-Relationship Model.* Denmark: IT University of Copenhagen.

Patrick, K., Griswold, W. G., Raab, F., & Intille, S. S. (2008). Health and the Mobile Phone. *American Journal of Preventive Medicine, 35(2)*, 177.

Pigford, D. V., & Baur, G. (1994). *Expert Systems for Business.* Wadsworth Publishing Company.

Poon, E. G., Keohane, C. A., Yoon, C. S., Ditmore, M., Bane, A., Levtzion-Korach, O., & Churchill, W. W. (2010). Effect of Bar-Code Technology on the Safety of Medication Administration. *New England Journal of Medicine, 362(18)*, 1698-1707.

Probst, Y. C., & Tapsell, L. C. (2005). Overview of Computerized Dietary Assessment Programs for Research and Practice in Nutrition Education. *Journal of Nutrition Education and Behavior, 37(1)*, 20-26.

Quesada, C., & Jenkins, M. (2013). A model Mobile Expert System for Nutritional Diagnosis.

Recommended Dietary Allowances (RDAs) and Adequate Intakes (AIs), Food & Nutrition Board, Institute of Medicine, National Academy of Sciences (NAS), 1998 - 2010

Research Council (US) Subcommittee on the Tenth Edition of the Recommended Dietary Allowances. (1989, January 01). Definition and Applications. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK234926/

Riccardi, G. (2002). *Database Management with Website Development Applications* . New Jersey : Pearson Education.

Robinson, S. M., Marriott, L. D., Crozier, S. R., Harvey, N. C., Gale, C. R., Inskip, H. M., & Cooper, C. (2009). Variations in Infant Feeding Practice are Associated with Body Composition in Childhood: A Prospective Cohort Study. *The Journal of Clinical Endocrinology & Metabolism, 94(8)*, 2799-2805.

Rollo, M. E. (2012). *An Innovative Approach to the Assessment of Nutrient Intake in Adults with type 2 Diabetes: The Development, Trial and Evaluation of a Mobile Phone Photo/Voice Dietary Record.*

Rutishauser, I. H., Black, A. E., Gibney, M. J., Vorster, H. H., & Kok, F. J. (2002). Measuring Food Intake. *Introduction to Human Nutrition*, 225-248.

Shakarian, A., & Haraldsdottir, A. (2001). *Required Total System Performance and Results of a Short Term Conflict alert Simulation Study. In 4th US/Europe Air Traffic Management R & D Seminar.* Sante Fe.

Shubhmeet , K. (2015, November). A Review of Software Development Life Cycle Models. *International Journal of Advanced Research in Computer Science and Software Engineering*.

Shuttleworth, M. (2008). *Qualitative and quantitative research design.* Michigan: Michigan University Press.

Sun, C., Foskey, R. J., Allen, K. J., Dharmage, S. C., Koplin, J. J., Ponsonby, A. L., ... & Wake, M. (2016). The impact of timing of introduction of solids on infant body mass index. *The Journal of Pediatrics*, *179*, 104-110.

Thomson, A. (2016, May 05). Hot Startups Using Artificial Intelligence in Nutrition. Retrieved from http://blog.ventureradar.com/2016/05/05/hot-startups-using-artificial-intelligence-in-nutrition/

Togai, M., & Watanabe, H. (1986). A VLSI implementation of a fuzzy-inference engine: Toward an expert system on a chip. *Information Sciences, 38(2)*, 147-163.

Wang, J. Z., Li, J., & Wiederhold, G. (2001). SIMPLIcity: Semantics-sensitive integrated matching for picture libraries. *IEEE Transactions on pattern analysis and machine intelligence, 23(9)*, 947-963.

Welcome to the USDA Food Composition Databases. (2015). Retrieved from https://ndb.nal.usda.gov/ndb/

West, C. E., Eilander, A., & van Lieshout, M. (2002). Consequences of Revised Estimates of Carotenoid Bioefficacy for Dietary Control of Vitamin A Deficiency in Developing Countries. *The Journal of Nutrition, 132(9)*, 2920S-2926S.

WHO. (2005). *The World Health Report: 2005: Make Every Mother and Child Count: Overview.* Geneva.

WHO. (2010). *World health statistics 2010. World Health Organization.*

WHO, J., & Consultation, F. E. (2003). *Diet, Nutrition and the Prevention of Chronic Diseases. World Health Organ Tech Rep Ser, 916(i-viii).*

Wing, R. R., & Phelan, S. (2005). Long-term Weight Loss Maintenance. *The American Journal of Clinical Nutrition, 82(1)*, 222S-225S.

Wojtusiak, J., Gewa, C. A., & Pawloski, L. R. (2011). Dietary Assessment in Africa: Integration with Innovative Technology . *African Journal of Food, Agriculture, Nutrition and Development, 11(7)*, 5629-5645.

Zanovec, M., O'Neil, C. E., Keast, D. R., Fulgoni, V. L., & Nicklas, T. A. (2010). Lean beef contributes significant amounts of key nutrients to the diets of US adults: National Health and Nutrition Examination Survey 1999-2004. *Nutrition Research, 30(6)*, 375-381.

Appendices

Appendix A: Questionnaire

Dear Respondent,

My name is Hope Machira, currently, a graduate student pursuing a Masters in Computer Based Information Systems at Strathmore University. I am undertaking a research a research in MEASURING NUTRITIONAL VALUE OF FOODS FOR INFANTS. You have been selected to form part of the study. I kindly request you to complete the questionnaire below. Any information we shall collect from you is for the purpose of the research only and will be treated with the utmost confidentiality.

Kind regards,

Hope Machira

*__Required__

Section A: General Information

A.1 Please select your age bracket (Single selection)

[ ] Below 21 years

[ ] 21-29 years

[ ] 30-40 years

[ ] Above 40 years

A.2 What is you highest level of education? (Single selection)

[ ] Primary School

[ ] Secondary

[ ] Tertiary/College

[ ] University

[ ] Postgraduate

Section B: Determining the Nutritional of Food

B.1 *Do you know the nutritional value of the food you feed the infant?

[ ] Yes

[ ] No

[ ] Maybe

B.2 *Do you feed all the essential nutrients the infant needs in a day?

[ ] Yes

[ ] No

[ ] Maybe

B.3 *What is your main source of advice on nutrition for the infant?

[ ] Hospital

[ ] Internet

[ ] Books

[ ] Others

If other, please specify

B.4 *What challenges did you face while using the above method to determine the nutritional value of food?

[ ] Information is not readily available

[ ] Cannot recall the foods you fed the infant

[ ] Ambiguous or unclear information

B.5 *Do you think that nutrition information is important for an infant?

[ ] Yes

[ ] No

Section C: User Requirements Gathering

C.1 * Do you feed you infant with these categories of nutrients?

	Yes	No	Maybe
Minerals	☐	☐	☐
Vitamins	☐	☐	☐
Carbohydrates	☐	☐	☐
Proteins	☐	☐	☐
Water	☐	☐	☐

C.2 *What method do you use to cook the infant's food?

[ ] Boiling

[ ] Frying

C.3 If a computer/mobile application system that can measure the nutritional level of food is implemented, I believe that feeding healthy meal options will be easier?

[ ] Strongly Agree

[ ] Agree

[ ] Neutral

[ ] Disagree

[ ] Strongly Disagree

Appendix B Usability Testing Questionnaire

Model for Generating Healthy Meals for Infants Usability Testing

Kindly self-register and register the infant

***Required**

D.1 *Were you able to login?

D.2 If the above answer is No, kindly list the problems encountered.

D.3 *Was the tool satisfactory in advising you on infant meal?

D.4*How would you rate the whole application? Tick only once per row.

	Poor	Fair	Good	Very Good	Excellent
Navigability	☐	☐	☐	☐	☐
Easy to use	☐	☐	☐	☐	☐
User friendly	☐	☐	☐	☐	☐
Responsiveness	☐	☐	☐	☐	☐
Useful and satisfying	☐	☐	☐	☐	☐

D.4 Any comments or suggestions about this application

____

____

____

*** *Thanks for your response****

Appendix C: Turnitin Originality Report

Turnitin Originality Report

6th by Hope Njeri

From 2016 Plagiarism Check (GS) (Library Services Plagiarism Checker (2016+))

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6 < 1% match (student papers from 08-Feb-2014)

Appendix D: Pseudo_Code

```
                    $infant_id = selectInfant();
                    if(showMealSchedule($infant_id)){
                            showMealSchedule($infant_id);
                    }
}
else{
$age = getAge($infant_id);
$rda = getRDA($age);
$feeding_requirement = getFeedingRequirement($infant_id);
generateMealSchedule($infant_id,$age,$rda,$feeding_requirement);
}
function selectInfant(){
        return $infant_id;
}

function getAge($infant_id){
return $age;
}
function getRDA($age){
    return $rda;

}

function getFeedingRequirement($infant_id){
        return $feeding_requirement;

}
function generateMealSchedule($infant_id,$age,$rda,$feeding_requirement){
        return showMealSchedule($infant_id);
}
function showMealSchedule($infant_id){
        return $meal_schedule;
}
```