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Improving the Allocation of Unused Food: Decision Support to Foodbank Johannesburg



by

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ABSTRACT

Foodbanking in South Africa is still a relatively new and unknown concept. South Africa has more than 11 million people who are food insecure, thus dependent on the aid of non-profit organizations such as foodbanks. Foodbank South Africa is a non-profit organization that strives to narrow the gap between excess and need by receiving and distributing unwanted food in our communities. Foodbank strives to involve the public, the commercial sector and social organizations to integrate and address the hunger problem as a joint system.

There are numerous facets in foodbanking that require deeper study for improvement as the demand for food is ever-increasing whilst large amounts of consumable food are still going to waste. This study aims to develop a quantitative method to make food allocation decisions at Foodbank Johannesburg. A standardized allocation system will help Foodbank JHB to make better use of its food resources, depend less on human judgment and assist in planning and decision-making.

The following data preparations were required prior to the model formulation: The breakdown of food dietary groups, the classification of agency types, the definition of the agencies' dietary requirements, and finally the analysis of historical inflow of donations. A forecasting system of the expected food donations is determined by studying historic data. Finally a mathematical model is formulated that calculates the various food types and quantities allocated to each agency. Linear programming is used as an optimization tool.

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NOMENCLATURE

Agencies:	Community based organizations that are supplied with food from foodbank e.g. shelters, clinics, orphanages, soup kitchens and school feeding programs
Beneficiaries:	The individuals that receive food from the agencies
GFN:	Global Foodbanking Network
FAO:	Food and Agriculture Organization of the United Nations
FIFO:	'First in first out' inventory issuing policy
FMCG:	Fast moving consumer goods
NPO:	Non-profit organization
OR:	Operational Research

CHAPTER 1

INTRODUCTION

1.1. An Overview of Foodbanking

1.1.1. Foodbanking in South Africa

In 2008, Foodbank South Africa was established as a non-profit organization under the leadership of the Global Foodbanking Network. The GFN has aided numerous other countries in establishing their own foodbanking networks and offers their expertise particularly in developing countries. The first Foodbank branch was opened in Cape Town and soon after others followed in Johannesburg, Port Elizabeth, Pietermaritzburg and Durban with new locations still emerging.

In the past three years, the operations of Foodbank South Africa have continued to grow rapidly, already increasing the number of beneficiaries (people dependent on Foodbank for food) to more than 200 000 people. It aims to function as a coordinated network with one common goal: to be a community asset that alleviates hunger.



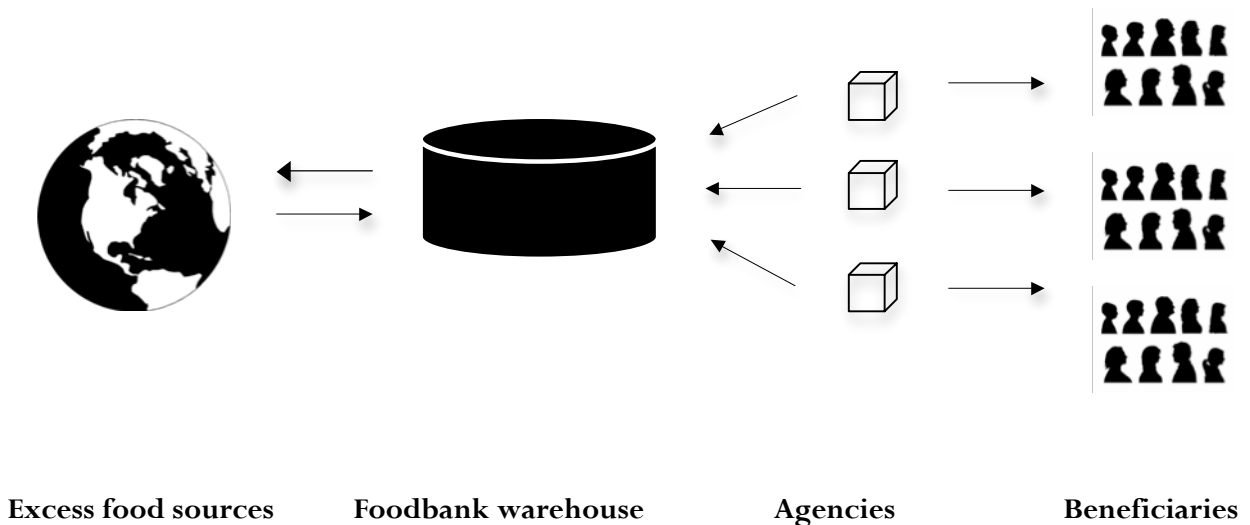
Figure 1.1. Logo of Foodbank South Africa

1.1.2. Foodbank Practices

The basic practice of a foodbank is to receive, collect and rescue unused and donated food or to receive financial donations from manufacturers, supermarkets, producers or any other willing source. All the food is taken to a central point (usually a large warehouse) where sorting, defacing of labels, storing and apportionment occur.

Social service organizations, referred to as ‘agencies’, apply for support from the foodbank and are once approved invited to come and collect food from the foodbank warehouse. Each agency is then responsible for providing its own beneficiaries with the received food through different feeding programs.

Figure 1.2. Flow of food in the foodbanking process



1.2. Organizational Background

1.2.1. Foodbank Johannesburg

The Foodbank SA branch in Johannesburg reaches a significant higher number of beneficiaries than the rest of the country's foodbanks. Currently, more than 300 agencies (which finally provides to thousands of beneficiaries) depend on this branch's services to provide food security to its beneficiaries. These agencies are largely spread out over the greater Johannesburg area and many of them serve people from deeply poverty-stricken regions.

Except for the high number of current annual registered agencies, there are hundreds of other agencies on a waiting list who also wish to receive food aid from Foodbank JHB. There is a clear need for further growth and improvement of the organization's system as the demand for food and number of agencies is continually rising, while their supply of incoming food might not necessarily increase in proportion.

1.2.2. Problem Definition

Although Foodbank JHB already plays a major constructive role in aiding and relieving hunger in the Johannesburg community, it is still in the process of establishing and developing its operations.

There are still many unreached beneficiaries in need and the number is rising. Therefore, growth and improvement of current operations are essential.

The key problem areas at Foodbank JHB were classified as follow:

1.2.2.1. High demand of Food

A large number of people live in poverty conditions in the Johannesburg area and depend on others for food security. At the same time the costs of living is continuing to rise with high food prices and fast increasing fuel cost reducing people's buying power. This means that additional demand is placed on the food system and more people are under-nourished. Additionally, companies that usually support Foodbank may be forced to cut back on donations in tough economic times.

Foodbank JHB has a long list of agencies waiting to receive food support. These agencies can only be helped once their current registered agencies are served. Hence full utilization of food resources is critical.

1.2.2.2. Volatility of Food Supply

Food donations are sent to Foodbank from a variety of companies. Some organizations donate food quantities on a regular basis as part of their own social responsibility contributions that can easily be foreseen and planned. Other reasons for donations include over-production, inaccurate sales forecasts, minor defects, strict quality requirements and packaging damage. These events can occur at any point in time and are therefore more complex to anticipate and plan for in advance. Variation in the market demand, seasonality and price changes also mean that there are high donation periods and low donation periods. In contradiction, agencies have agreed that they prefer consistent, regular amounts of food to larger quantities with fluctuations.

1.2.2.3. Perishable Food Products

Currently the Foodbank warehouse has no cold chain storage facilities. Consequently perishable food items that come in as donations must be allocated and collected by agencies within a very short timeframe. The perishable food products require rapid management and allocation to prevent food going to waste before it reaches beneficiaries.

1.2.2.4. Agency related issues

Currently, the registered agencies receive food on irregular occasions. An agency is notified to come for collection immediately. Some food types are highly perishable, so the agencies are expected to respond quickly and come for collection immediately.

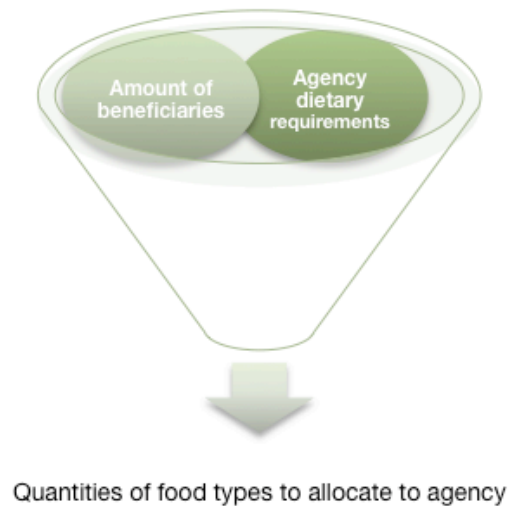
An individual in charge of the warehouse manages the whole allocation process food manually. Decision-making is based on an estimation of quantities of food observed in stock. Presently, the different requirements of agencies are not considered as all agencies receive more or less equal amounts of food available in stock. This means that on a specific day, for example, a nursery school of 15 children receives exactly the same type and quantities of food as a soup kitchen with 60 adult beneficiaries. Clearly, the needs of these agencies will differ and must be taken into account.

1.3. Project Aim

The problem that will be addressed in this project specifically lies in the process of allocating food to the registered agencies. Currently, Foodbank uses a manual system mainly based on human judgment. Stock levels are physically observed and divided into even-sized groups. Based on the volume of donations received, a certain amount of agencies are notified to turn up for collection. As a result the quantities and type of food given out to agencies often vary and a balanced food offering cannot be guaranteed.

The aim of this project is to develop an alternative allocation system to calculate the quantities and food types to allocate to each agency. The main drivers of decision will be the agency type (e.g. orphanage) and the number of beneficiaries supported by the particular agency. To attain this, a considerable amount of data preparation is needed. Firstly, the food products received as donations will be organized into appropriate food groups. Further, the registered agencies at Foodbank will be examined and classified into agency types with the goal of defining their specific dietary requirements. The cost of food products will also be considered and an average monetary value assigned to each food group. A mathematical model can then be formulated that quantitatively calculates the optimal allocation.

Figure 1.3. Basic graphical explanation of the allocation model



CHAPTER 2

LITERATURE REVIEW

2.1. Food insecurity and waste

Food insecurity can be described as a lack of access to sufficient amounts of safe and nutritious food. This may be due to unavailability, inadequate purchasing power or ineffective utilization on household level.

South Africa has been identified as one of the few countries that has the capacity to provide its people with enough food. This basic right is entrenched in the Bill of Rights and states that every citizen has the right to have access to sufficient food and water. (Constitution of South Africa, 1996) Nevertheless, the reality is that a quarter of our population does not know where their next meal is coming from. (Stats SA, 2010)

The Food and Agriculture Organization of the United Nations revealed in 2011 that one third of the food produced in the world for human consumption- approximately 1.3 billion tons- gets lost or wasted every year. (FAO, 2011)

This alarming amount of waste may be as a result of seasonality, over-production, incorrect labeling or any minor product defects detected.

Wastage occurs at all stages of the life cycle of food, starting from harvesting, through processing, distribution and finally on household level. Some of the incurred food wastes may not be suitable for human consumption, although a large portion is still in acceptable condition and could still be consumed without risk.

The best wastage prevention measure is to accurately foresee and plan food production and distribution according to specific needs. However, changes in the market environment and various unavoidable factors, make the exact implementation thereof difficult to attain. Schneider (2008) suggests that ‘the second best prevention measure against unnecessary waste is the use of those food items off the usual market. There are a number of hunger relief and non-profit organizations in South Africa that aim to utilize the great quantities of food waste for people in need. Some of these organizations include food banks, shelters, soup kitchens, childcare centers and food rescue programs.

2.2. Forecasting

2.2.1. Forecasting Food Supply

All products donated to Foodbank can be classified as fast moving consumer goods (FMCG). These products have relatively short shelf lives as a result of high demand and perishability of certain food products.

The main attributes of FMCG from a consumer and marketer’s view have been identified as:

- Low price
- High volumes
- Frequent purchase
- Low involvement from consumers
- Extensive distribution networks
- Low contribution margins
- High stock turnover

(Majumdar, 2004)

Overall, food companies are more concerned with forecasting than other industries due to their special characteristics, such as the need to maintain high product quality and the uncertainty and variation in consumer demands.

In order to effectively plan an allocation method of food items to the different agencies, a prediction of the inflow of food donations is important.

Interestingly, Foodbank's supply actually depends on the incorrect sales forecast by retailers and producers. The excess amounts of unsold food are sent to Foodbank as donations. A recent initiative of several large companies in the food industry aiming to improve forecasting practice, showed that an unexpected 48% of food companies are poor at forecasting. (Adebanjo & Mann, 2000) The variations in consumer demand are mostly caused by factors like price, promotions, changing consumer preferences or weather changes. (Van der Vorst, Beulens, De Wit, & Van Beek, 1998)

Most research available on forecasting is primarily on the prediction of demand. This model is unique in the sense that demand can be assumed deterministic (the hungry people in need) and the supply of food donations is stochastic (the supply of donations). It is also reasonable to assume that the demand will always exceed supply. Normally, the questions asked in managing inventory are how much to order and when. In this case we are primarily interested on how much to hand out.



Figure 2.1. The nature of Foodbank's supply and demand

2.2.2. Forecasting Methods

In business applications, forecasting serves as a strong starting point for major decision-making in finance, marketing, productions and purchasing.

There are two broad categories of forecasting methods: quantitative and qualitative methods. Quantitative methods are based on algorithms of varying complexity, while qualitative techniques depend on subjective judgment.

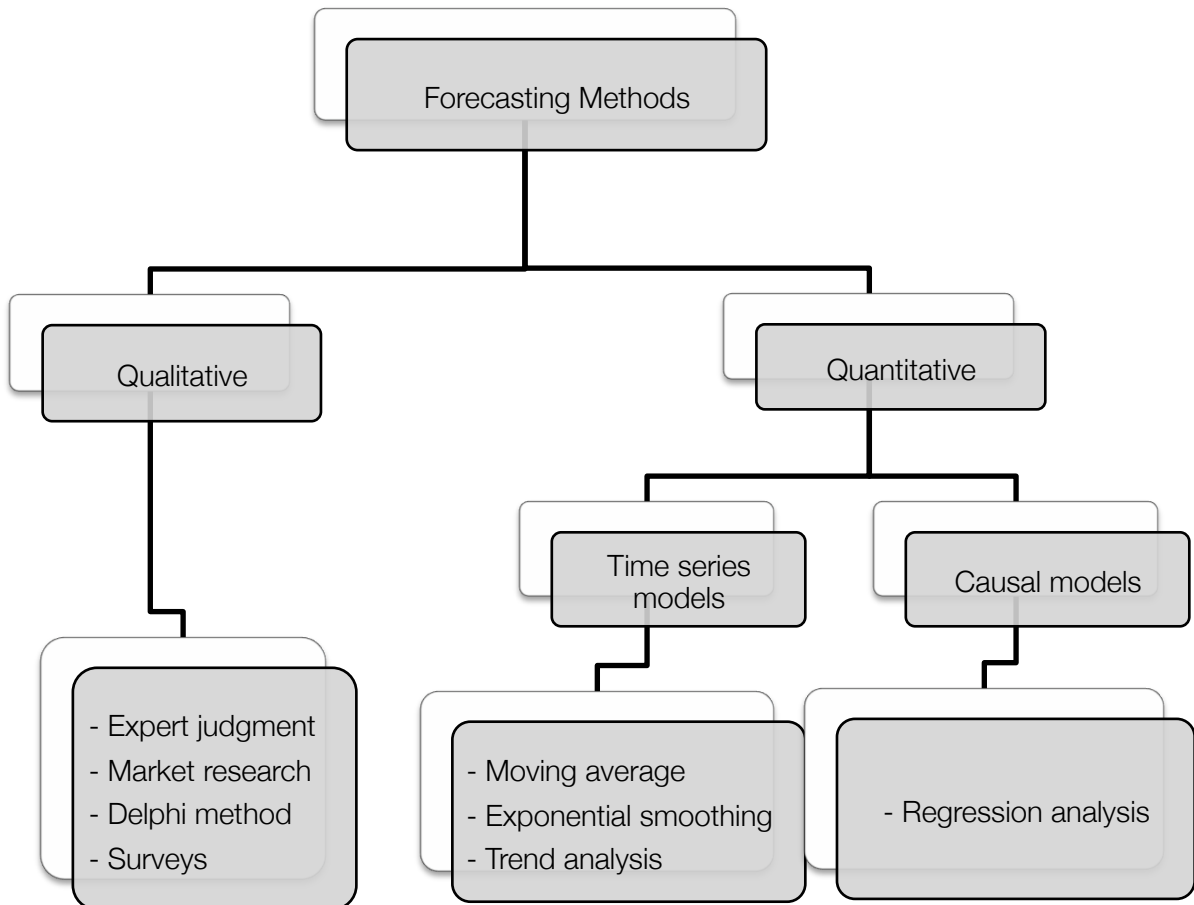


Figure 2.2. The breakdown of forecasting method categories

Expert judgment, market research, the Delphi method and surveys are all qualitative techniques that depend on subjective opinions to form a forecast.

Time series, a quantitative technique, is based on the analysis of historical data. The assumption is made that past patterns in data can be used to forecast future data points. Commonly used time series techniques include moving average, exponential smoothing and trend adjustments.

In the moving average technique (simple moving average or weighted moving average) the forecast is based on the arithmetic average of a number of given data points. Exponential smoothing is built on the premise that more recent observations might have stronger prediction value for the future. In trend analysis, cycles, seasonality and irregular variations are looked for in order to identify tendencies that may predict future behavior.

Causal forecasting methods are based on a known or apparent relationship between the factor to be forecast and other external or internal factors. In regression analysis, mathematical equations relate a dependable variable to one or more independent variables.

In this study, advanced time series analysis software was made use of in the attempt to forecast the supply of donations. The software automatically determines the best time series technique to apply on each data series and generates the most probable forecast. The process followed and the results obtained in the forecasting study are explained in Chapter 4.

2.3. Basic dietary requirements

Decision-making in the allocation of food will ask that the minimum dietary requirement of a beneficiary be known. The correct balance of food groups will be another crucial aspect to consider. Understandably, this will vary by the sex, age and health condition of an individual. These aspects will be studied so as to correctly define the food groups and agency group types needed in the data preparation later in the study.

The six main nutritional groups the human body requires have widely been defined as:

- Carbohydrates
- Proteins
- Fats
- Vitamins
- Minerals
- Water

These nutrients are best found in fruit and vegetables, starchy food, such as pasta, bread and potatoes, meat, fish, eggs and beans, milk and dairy foods and food containing fat and sugar.

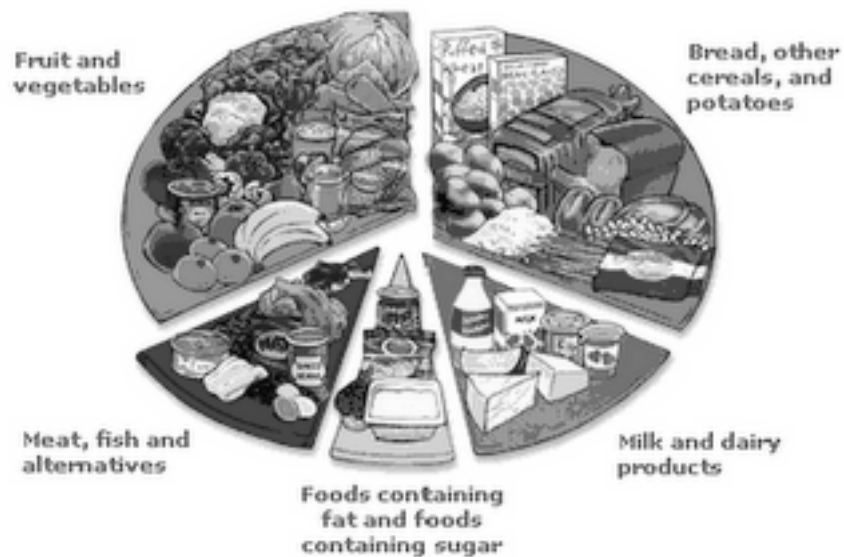


Figure 2.3. The recommended ratio of food groups in a healthy, balanced diet

Foodbank provides for a wide variety of different demographical groups e.g. pre-schools, orphanages, old age homes and health care centers. It is therefore important to distinguish between different agency types, since their dietary requirements will vary.

The Food and Agricultural Organization supplies the following dietary guidelines for specific profile groups:

Vulnerable/sick people:

Variety and balance in the diet is important to fight the illness, strengthen the body and prevent weight loss. Small, frequent meals with a variety of foods are recommended with plenty of liquids and fresh vegetables and fruit.

Elderly people:

Older people may need less food as they are less active, but quality and variety is still essential. Smaller amounts of foods, which provide energy e.g. fats, and oils, staple foods and sugars are important. To keep them in good health and protect against illnesses, fresh vegetables, fruit and protein are important.

Youth:

Children need to eat healthy and balanced meals as they are growing and developing fast. For this reason, increased amount of food that provides energy must be incorporated in their diets- starchy foods, protein and vegetables and fruit are all important.

(FAO, 2004)

These basic dietary guidelines, together with input from Foodbank, will direct the grouping of food products, the agency types and the definition of their dietary requirements.

2.4. Linear Programming

Linear Programming is a member of the general class of Operational Research mathematical programming techniques and used worldwide in different problem solving applications. Other members are techniques such as dynamic programming, quadratic programming, stochastic linear programming and mixed integer programming and non-linear programming.

The scientist George B. Dantzig developed linear Programming (LP) as a discipline during the Second World War in Germany. The technique was regarded as “theoretical” until the advent of digital computers at which time LP applications advanced rapidly in especially the industry for example in the crude oil refining industry. Up to two decades ago, LP could only be executed on large mainframe computers but today very large real world LP applications find application on personal computers in industries as diverse as logistics, aircrew scheduling, mining, banking and numerous other fields.

2.4.2. Linear Programming Software

Spreadsheet applications are widely used all over the world, however, due to certain limits such as the number of spreadsheet columns, software development companies developed so-called, matrix generators. Matrix generators read the data from text files/databases/spreadsheets and then generate a matrix according to the code programmed by the mathematical programmer. This way, matrices become data driven and generic in that the user can change the input data in a user-friendly spreadsheet. Matrix generators are normally linked to optimizers, where the matrix is read into the optimizer with a view to optimizing the matrix. The optimal solution found by the optimizer is then read by the matrix generator, once again according to the code of the mathematical programmer and a user friendly report is generated and can be printed for use by the users and associated staff.

There are many optimizers on the market and certain versions can be downloaded from the Internet. It is, however, good practice to make use of a trusted and mature optimizer. The matrix generator and optimizer used in this study are OMNI and CPLEX respectively. The flow of data to matrix generator to optimizers to the report is transparent to the user. In this study the matrix generator is coded to regard the “food groups”, “agencies” and “agency types” as generic. The practical implication hereof is that the user can define any number of mentioned generic classes in the spreadsheet and a matrix will be generated accordingly. This is a very useful feature in cases of expansion or even contraction that may occur in the value chain.

** Note: OMNI is a product of Haverly Inc. of New Jersey in the USA and CPLEX is a product of the CPLEX Corporation amalgamated with IBM.*

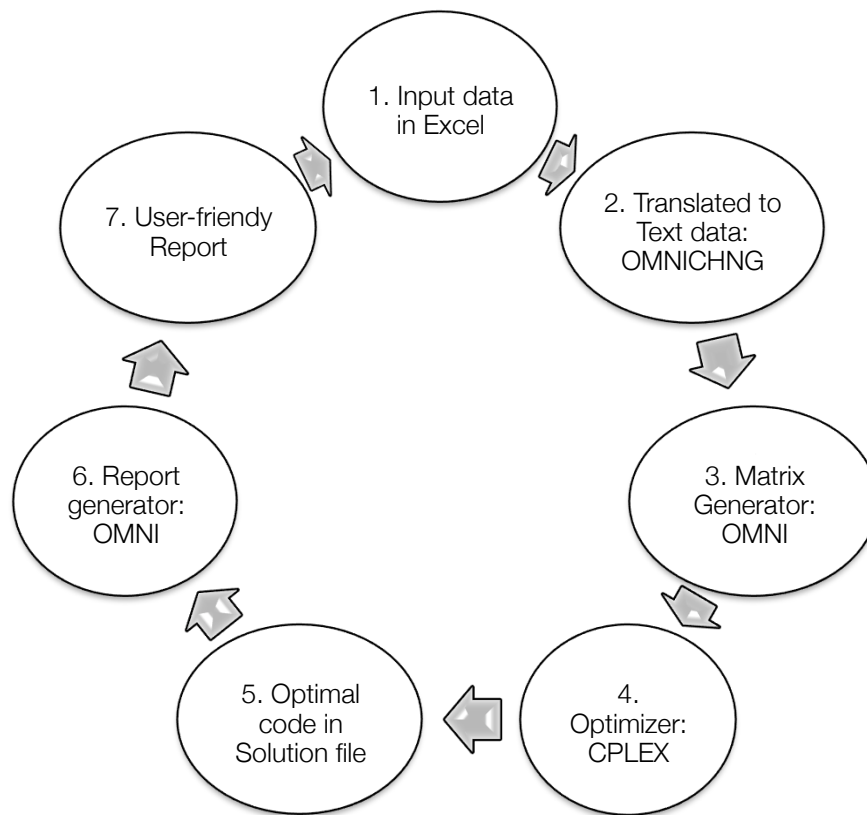


Figure 2.4. Graphical description of LP software used: OMNI

CHAPTER 3

DATA PREPARATION

3.1. Food Group Classification

The assortment of products that has historically been recorded as donations was carefully analyzed and sorted. As a starting point the wide range of food products (approximately 1700) were grouped into 16 main groups:

- Baked goods
- Canned foods
- Dairy
- Dry goods
- Eggs
- Fruit
- Rice/pasta
- Vegetables
- Baby products
- Cereal
- Cold beverages
- Condiments
- Detergents
- Luxuries
- Sandwich spreads
- Toiletries

The groups were formed on the bases that each groups fulfills a specific dietary requirement and also has its own appropriate unit of measure. The model will handle these groups as generic and make provision for them to be modified or altered as needed.

In the next step the food groups were divided by distinguishing between perishable and non-perishable products. In effect, this will determine either whether a product type may be kept as stock or whether it needs to be allocated immediately. As mentioned before, Foodbank does not have access to cold chain storage facilities. Therefore, perishable products must be allocated immediately on a First-in-first-out (FIFO) principle.

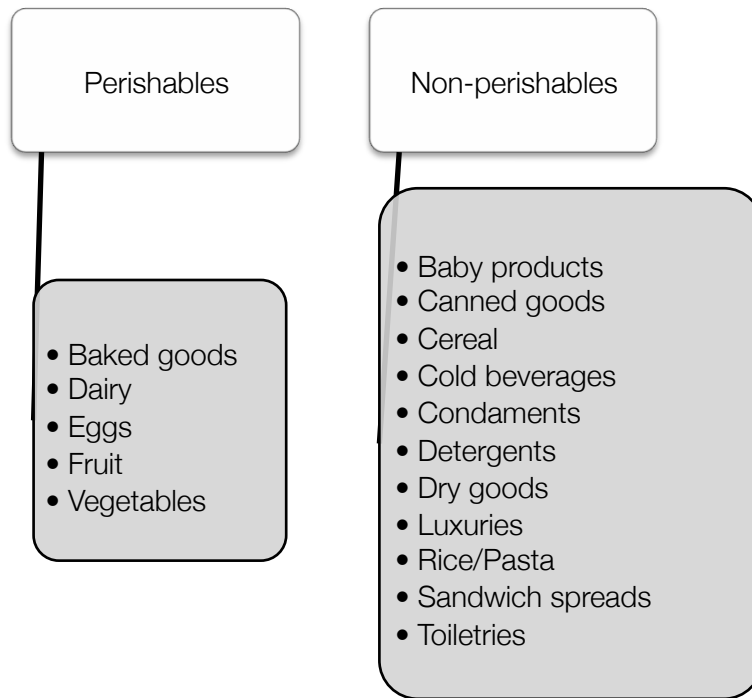


Figure 3.1. Classification of perishable and non-perishable product groups

The products received at Foodbank are not only food types that satisfy basic dietary requirements, but also other extra “luxury” products (e.g. sweets, biscuits, puddings). Therefore it is important to differentiate between basic food types that are considered as necessities and other supplementary donations.

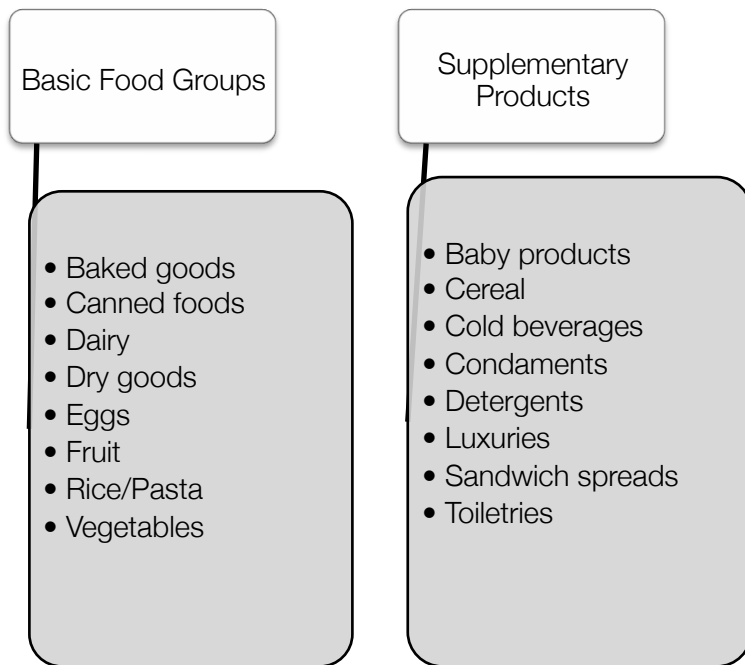


Figure 3.2. Classification of basic food groups and supplementary products

Agency minimum dietary requirements will only be expressed in terms of the basic food groups. However, it is important that priority is given to specific agency types for some supplementary products. As an example, in the case where a donation of baby products are received, although it is viewed as an “extra”, it should rather be allocated to day care centers as opposed to old age homes. This matter will further be discussed in the model formulation.

3.2. Agency Classification and Dietary requirements

Foodbank JHB currently serves 378 agencies on a monthly basis, which supports a total of more than 102 000 beneficiaries over the greater Johannesburg area.

There are three target areas that these agencies aim to serve in:

- **Child & Youth Development:** Pre-schools, Foster care, Shelters for orphans and vulnerable children, School feeding schemes
- **Adult Development** Nutritional feeding centers, Soup kitchens for the unemployed, HIV-positive and pregnant women
- **Social Welfare** Aged care, Disabled care, Care for the terminally ill

From a modeling point of view, the different needs of the registered agencies must be defined in order to make allocation decisions. It was decided to classify the list of agencies into main 5 categories that are expected to have similar needs.

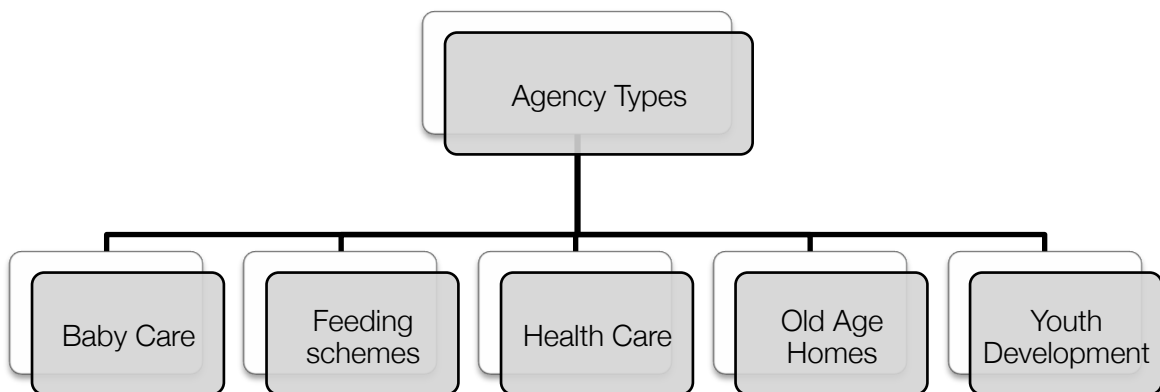


Figure 3.3. Categorization of agency types

It is important to note that each agency follows its own feeding policy. The degree of food assistance it offers to its beneficiaries varies over the different agencies.

To illustrate, a soup kitchen may support over 500 beneficiaries, but in some instances only do so once a week. In order to be fair, this must be compared to a nursery school of 30 children that feeds its dependants everyday. The identification of dietary needs can become a difficult process, as each agency undoubtedly would want the maximum amount of food it can obtain.

Evidently, a level of control is needed from Foodbank to ensure that the requirements are defined justly. An agency manager has recently been appointed, who primarily focuses on agency-related issues. Regular agency inspections are arranged to assess whether the food received is used for the purposes it was intended for. These inspections may help to correctly identify the agencies' specific needs for the allocation model.

As previously mentioned, there will be two main drivers that will determine an agency's specific dietary requirements:

- 1.) The type of agency
- 2.) The number of beneficiaries supported by the agency

1.) Type of Agency

Each agency type (e.g. Baby Care) will have its own unique profile of requirements.

The food requirements are defined per beneficiary in a specific agency type for each food group.

Example:

The agency A.B.C. Day Care Centre has 76 babies in their care. It will fall under the defined agency type Baby Care. Therefore every beneficiary will need the established minimum of:

- 0 Kg *Baked goods*
- 0 410g can *Canned foods*
- 2L *Dairy*
- 0.2 Kg *Dry goods*
- 0.25 dozen *Eggs*
- 0.2Kg *Fruit*
- 0 Kg *Rice/Pasta*
- 0.5 Kg *Vegetables*

2.) The number of beneficiaries

The dietary needs per beneficiary for a specific agency type will then be multiplied by the number of beneficiaries supported to come to the total dietary requirements of a specific agency.

Example:

The Total needs of A.B.C. Day Care Centre can thus be determined as:

•	0	x 76	=	0 Kg	Baked goods
•	0	x 76	=	0 410g can	Canned foods
•	2	x 76	=	152 L	Dairy
•	0.2	x 76	=	15.2 Kg	Dry goods
•	0.25	x 76	=	19 dozen	Eggs
•	0.2	x 76	=	15.2 Kg	Fruit
•	0	x 76	=	0 Kg	Rice/Pasta
•	0.5	x 76	=	38 Kg	Vegetables

3.3. Cost

As Foodbank is a non-profit organization, the aim is to provide hunger relief for as many people as possible, subject to limited funding. The organization receives food donations as well as financial support from various contributors. Financial donations are used to make additional food purchases of a few basic products to fill shortages (often at special discounted prices). It is therefore adequate to consider a model, which assists the manager with allocation and purchasing decisions that fulfills the agencies' needs at the lowest possible cost.

The model will facilitate the allocation process, but also make procurement decisions. The average procurement cost of each food group per unit of measure is therefore required. This will be used to calculate the quantities of each food group to additionally purchase so as to meet requirements. Foodbank's most recent procurement price lists (August 2012) and the South African food cost report were used to calculate the average price per unit for each food group.

Food Groups	Unit of Measure	Procurement Products & Price per unit	Product Procurement Ratio	Weighted Average Price per Unit
Baked Goods	Kg	Loaf bread (R5.80)	100%	R 5.80
Canned Foods	410g Can	Baked beans (R4.10)	50%	R 5.52
		Canned fish (R7.83)	25%	
		Tinned veg (R6.05)	25%	
Dairy	L	Long life milk (R4.09)	100%	R 4.09
Dry Goods	Kg	Cake flour (R5.81)	10%	R 4.24
		Maize (R3.29)	70%	
		Sugar (R6.80)	20%	
Eggs	Dozen	Eggs (14.60)	100%	R 14.60
Fruit	Kg	Apples (R2.44)	70%	R 3.96
		Bananas (R7.50)	30%	
Rice/Pasta	Kg	Rice (R11.62)	70%	R 12.16
		Pasta (R13.42)	30%	
Vegetables	Kg	Beetroot (R9.67)	10%	R 4.41
		Cabbage (R3.51)	30%	
		Butternut (R4.00)	30%	
		Carrots (R3.95)	30%	

Table 3.1. Average cost of food groups per unit of measure

CHAPTER 4

FORECASTING

Foodbank receives an array of different food products as donations from a variety of different suppliers and producers. This can make it an exceptionally difficult task to predict, as often it is precisely the result of poor forecasting of market demand that creates a surplus in production. These 'leftovers' are sent to Foodbank as donations.

However, an attempt to model these inflows as accurately as possible is imperative to plan an effective allocation process. In order to find an appropriate forecasting strategy, guidance was received from two valuable sources:

- Optimatix, a consulting company that specializes in mathematical optimization and demand forecasting
- The Department of Statistics of the University of Pretoria

The following steps were taken in coming to a realistic forecasting method:

1. Reports of March 2011 to July 2012 were obtained from Foodbank to analyze the inflow of donations.
2. A large database was set up that contains each of the 1600 product codes, its unit of measure, the opening stock, distribution, donations received and the closing stock of each item separately. The data was set up in a format on Excel that would be compatible with the forecasting software.
3. Optimatix Forecasting Software was used on the data, which operates by using a selection of statistical algorithms. The program considers a variety of quantitative techniques, automatically determines the best fit for the data, and provides the expected forecast as well as a wide range of statistical measures.

- The results generated and the statistical measures calculated by the software for each product type were carefully analyzed and assumptions were made on the reliability of the forecast.

From the results it was evident that most food product donations are exceptionally volatile. A large amount of intermittent data points exists that makes it difficult to generate a dependable forecast. Seasonality could also not be found, as the time frame of the data available is too short. (17 months)

To illustrate, if we look at the product BAKPASB001, we can see that over 6 months, from August 2011 to January 2012, no donations were received. In February 2012 there was a sudden donation of 497.5kg and afterwards no donations were received again until July 2012. A number of explanations may exist for sudden donations, such as a decrease in market demand for the product, over-production or minor product variation. However, from Foodbank's perspective, most of these reasons are unknown and currently impossible to foresee.

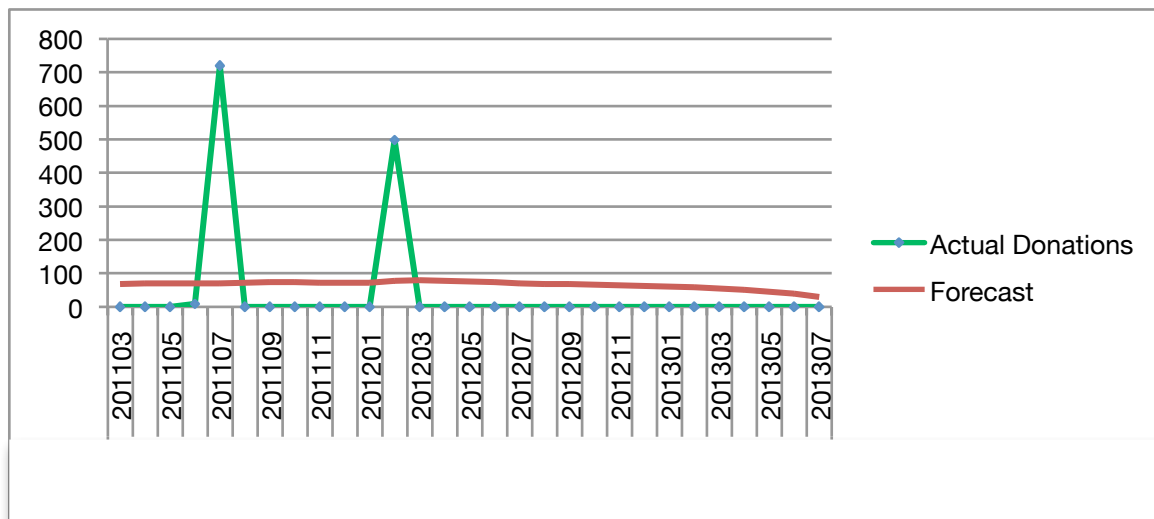


Figure 4.1. Plot of actual and foreseen donations (in kg) of product BAKPASB001

Adding food products in each category together and modeling each food group as a whole, showed better forecasting results. As an example, compare the generated forecast of BAKPASB001 with that of Baked Goods. Although it might not be possible to predict the exact donation per product of BAKPASB001, we can generate a rough estimation of the total quantity of baked goods expected to arrive. Linear exponential smoothing was used on this specific example.

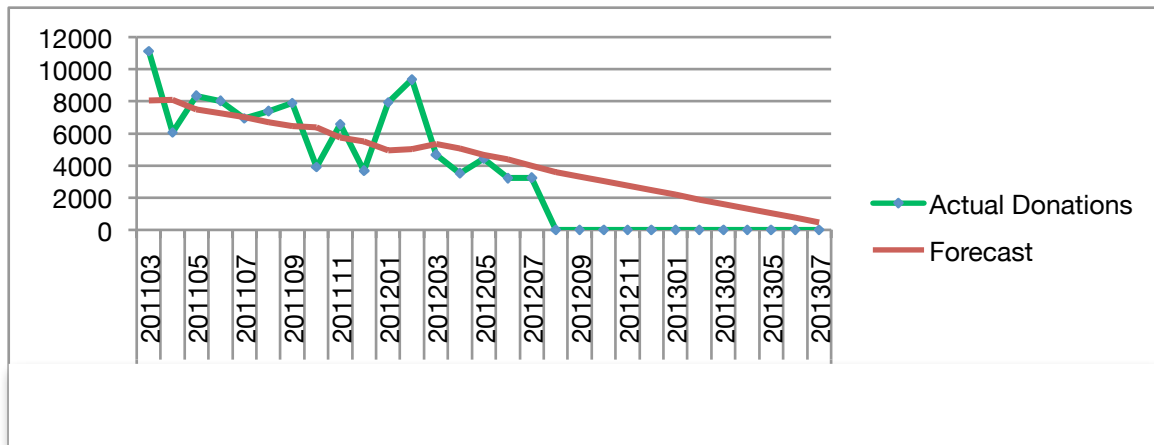
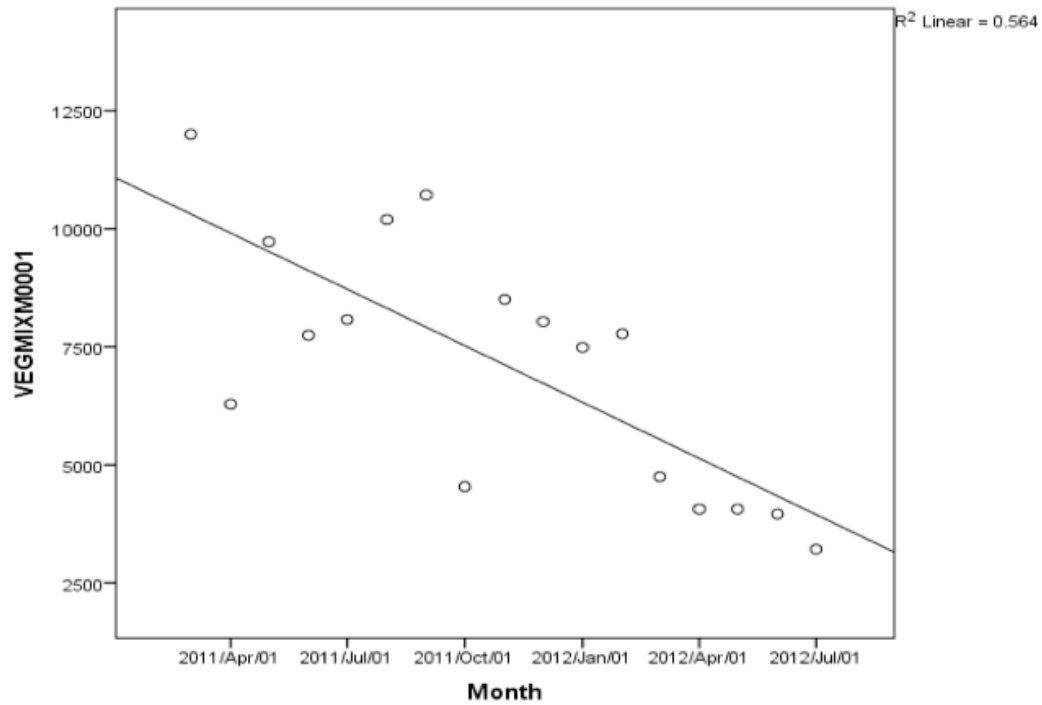


Figure 4.2. Plot of actual and foreseen donations (in kg) of the food group Baked Goods

In another attempt to assess the donation data, Spearman correlations were calculated for all the products that were received on a fairly regular basis. This was done in order to measure the statistical dependence between the quantity received and time passed. However, as many products were not received from the start of the measured time interval, or only received sporadically, not many useful assumptions could be made out of the results.

The Spearman correlation of product VEGMIXM0001 is shown as an example. A negative correlations implies that there was a steady decrease in the quantity received over time, while positive correlations signifies a steady increase. For this specific product code the correlation was negative, thus the product was received less frequently as time passed.



Clearly, there is still a need for a standardized, reliable prediction method for the inflow of donations. After a long process of considering different alternatives and measuring them against each other, it was decided that in this case, a forecasting system that depends on qualitative input might be more meaningful. Better communication with suppliers, managerial judgment and current market analysis will mean that general expectations of future donations can be formed and might even provide better results than quantitative techniques. However, it is important that this method of forecasting must still hold a level of objectivity and be performed in a standardized and reliable manner.

CHAPTER 5

THE ALLOCATION MODEL

5.1. Overview of the model

A number of general prerequisites were identified for the Foodbank allocation model.

- The key model objective is to serve as a planning tool that assigns donated products to specific agencies.
- The model must function on a monthly basis. It is part of Foodbank's policy to serve an agency once a month.
- Currently there is no quantitative allocation process in place and all decisions are made manually. The goal is to let the output of the model act as a general allocation plan for managers and staff members. The full day-to-day activities and exact implementation thereof still remain the tasks of the workers.
- All data fields must be accessible, nonspecific and receptive for modification at any point of time. (E.g. a new agency may be added to the list) This can be achieved by creating Excel input spreadsheets that will be easy to operate by the user. The data will then be translated to the optimizer software, processed and finally converted back to a user-friendly report.
- The minimum dietary requirements of the agencies must be met. Shortages will be filled by identifying the types and quantities of additional products to procure. It is therefore adequate to make the assumption that the optimal allocation plan will be where the agencies' minimum dietary requirements are met at the *lowest possible cost*.

5.2. Model Formulation

Sets

- A = set of Agencies
T = set of Agency Types
G = set of Food Groups

Decision variables

- X_{ga} = Amount of Food Group G to allocate to Agency A
 Y_g = Amount of Food Group G to Procure
 CS_g = Closing stock of Food Group G

Parameters

- B_a = Number of Beneficiaries in Agency A

 LB_{tg} = Minimum dietary requirements of a beneficiary in Agency Type T of Food Group G
 UB_{tg} = Maximum dietary requirements of a beneficiary in Agency Type T of Food Group G

 LH_{ga} = Minimum requirements of Agency A of Food Group G
 UH_{ga} = Maximum requirements of Agency A of Food Group G

 C_g = The Cost to procure one unit of measure of Food Group G
 OS_g = Opening stock of Food Group G
 US_g = Stock Capacity of Food Group G
 D_g = Donations expected of Food Group G

$$P_g = \begin{cases} 1 & - \text{ if Food Group G is Perishable} \\ 0 & - \text{ otherwise} \end{cases}$$

$$Q_g = \begin{cases} 1 & - \text{ if Food Group G is a Basic Food Group} \\ 0 & - \text{ otherwise} \end{cases}$$

$$R_{at} = \begin{cases} 1 & - \text{ if Agency A is an Agency Type T} \\ 0 & - \text{ otherwise} \end{cases}$$

$$\text{Minimize } z = \sum_g (C_g) (Y_g)$$

s.t.

$$t \sum (B_a) (LB_{tg}) (R_{at}) (Q_g) = LH_{ga} \quad \forall \quad G, A \quad (1)$$

$$t \sum (B_a) (UB_{tg}) (R_{at}) = UH_{ga} \quad \forall \quad G, A \quad (1)$$

$$X_{ga} \geq LH_{ga} \quad \forall \quad G, A \quad (2)$$

$$X_{ga} \leq UH_{ga} \quad \forall \quad G, A \quad (2)$$

$$CS_g \leq US_g \quad \forall \quad G \quad (3)$$

$$\sum_g (P_g) (CS_g) = 0 \quad (4)$$

$$OS_g + D_g + Y_g = \sum_a X_{ga} + CS_g \quad \forall G \quad (5)$$

$$\sum_t R_{at} = 1 \quad \forall A$$

$$X_{ga}, Y_g, CS_g \geq 0 \quad \forall G, A$$

As a starting point, it can be assumed that there is a set of agencies, A , registered for food support at Foodbank. Each of these agencies can be categorized into exactly one of the agency group types, T . The different food groups are defined as set G .

- Each of the agency types has a unique set of minimum and maximum dietary requirements per beneficiary for each food group. By using the amount of beneficiaries, it is then possible that the requirements can be expressed in terms of each agency's total needs. (Constraint 1.) Note that the beneficiary minimum requirements are only defined in terms of the basic food groups. The supplementary products will only be allocated as logically and fairly as possible among the agencies, but not viewed as a necessity. Thus the minimum requirements for supplementary products will be equal to zero for all agency types.
- Constraint (2) ensures that the amounts of allocated food groups fulfill the agencies' dietary requirements.
- Stock capacity of each food group is defined in constraint (3).
- A distinction is made between perishable and non-perishable food groups. This is so that perishables are not kept as stock (4), and all products are allocated to agencies.

- The food quantities in the inventory system, which comprises of the opening stock, donations received, allocated quantities and purchased items, are all balanced in equation (5)

The Objective function of the model is to minimize the total cost of food procurement needed to fill shortages. The model will ultimately determine how much to allocate to which agencies, what the closing stock should be and the procurement quantities needed to fill shortages.

CHAPTER 6

RESULTS

In an attempt to test the model, the latest monthly data available was used as a trial experiment. Seeing as historic data of up until July 2012 is available, the allocation plan of August 2012 was generated. An example of one of the agency allocation reports, A.B.C. Day Care Centre is shown in Figure 6.1. The main output report can be seen in Figure 6.2.

The minimum total cost of procurement generated by the program was calculated as R418 942.54. At this stage this seems realistic. It seems that the results for August look viable. However, data manipulation and different scenario testing will be important from now on to look for weaknesses and to further refine the model.

AGENCY :A.B.C. Day Care Centre		

FOOD TYPE	UNITS TO BE DESPATCHED	VALUE IN R
-----	-----	-----
BAKEDG	0	0.00
CANNED	0	0.00
DAIRY0	83	338.65
DRYG00	11	46.85
EGGS00	2	33.58
: FRUIT0	5	18.21
RICEPA	0	0.00
VEGETA	14	60.79
BABYPR	138	0.00
CEREAL	23	0.00
COLDBE	92	0.00
CONDAM	0	0.00
DETERG	23	0.00
LUXURI	0	0.00
SANDWI	0	0.00
TOILET	14	0.00

TOTAL		498.08

Figure 6.1. Output Allocation Report of A.B.C. Day Care Centre for August 2012

FOOD BANK JOHANNESBURG.

=====

OPTIMAL SOLUTION : MINIMUM COST TO PURCHASE SHORTAGES (R): 418942.56

SHORTAGE LIST

=====

FOOD TYPE	UNITS TO PURCHASE	UNIT COST R	TOTAL COST R	OPENING STOCK	DONATED TO FOODBANK	DESPATCHED TO AGENCIES	CLOSING STOCK
BAKEDG	7328	5.80	42504.72	0.00	3612.00	10940.40	0.00
CANNED	14377	5.52	79361.04	1631.00	804.00	16812.00	0.00
DAIRY0	25007	4.09	102280.27	0.00	3978.00	28985.40	0.00
DRYG00	0	4.24	0.00	7164.00	21805.00	17243.52	11725.48
EGGS00	4733	14.60	69106.18	0.00	466.00	5199.30	0.00
FRUIT0	7625	3.96	30178.56	0.00	1951.00	9575.70	0.00
RICEPA	4922	12.16	59856.38	0.00	0.00	4922.40	0.00
VEGETA	8094	4.41	35655.39	0.00	4041.00	12135.30	0.00
BABYPR	11010	0.00	0.00	512.00	427.00	11949.00	0.00
CEREAL	19901	0.00	0.00	1798.00	2109.00	23807.50	0.00
COLDBE	14142	0.00	0.00	792.00	4332.00	146566.00	0.00
CONDAM	5122	0.00	0.00	625.00	1183.00	6930.00	0.00
DETERG	7988	0.00	0.00	208.00	1816.00	10012.30	0.00
LUXURI	61863	0.00	0.00	76.00	524.00	62463.00	0.00
SANDWI	8406	0.00	0.00	0.00	0.00	8406.00	0.00
TOILET	11159	0.00	0.00	0.00	944.00	12102.90	0.00
TOTAL			418942.54				

=====

AGENCY :A.B.C. Day Care Centre

=====

Figure 6.2. Main Report for August 2012

Future Results

The implementation of a successful allocation system can generally present the following advantages to Foodbank and the agencies, respectively.

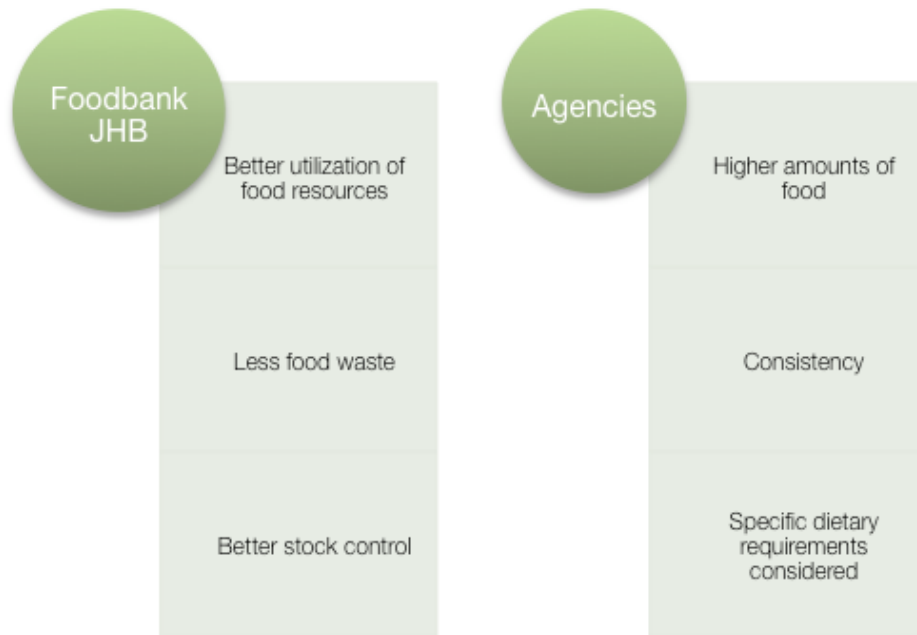


Figure 6.1. Advantages of an allocation system from the views of Foodbank and the agencies

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

Seeing as this is the first endeavor to develop a quantitative modeling system at Foodbank JHB, there are still a number of potential areas of refinement and improvement that can be considered.

- As a start, it may be useful to break the model up into smaller time frames in order to manage donation arrivals more realistically. The management of perishable items will also be more structured and can be planned better for. This will however mean that a more precise, timely accurate forecast will be required.
- The prediction of donations remains a challenge. Other areas such as market analysis; product demand and product lifetime averages can be investigated in order to make better future assumptions.
- A longer period of donation inflow data may provide more meaningful forecasting results. It is recommended that the inflows are continually monitored and recorded carefully so that a longer period can be analyzed than in this study (17 months). To detect seasonality, a minimum of 24 months is needed.
- On a more practical level, communication with potential donators might be the most effective anticipation method. A proper communication system can be designed that synchronizes activities between Foodbank and the potential donators.

- For dependable results, the input data for the allocation model must continually and accurately be updated. The product range will expand as new products emerge on the market and the registered agencies will change over time as new ones are added and some are removed. It is suggested that a specific person is made responsible for these modifications.
- Lastly, it is recommended that Foodbank investigate the option of investing in cold chain facilities in future. This will lengthen the lifetime of products in stock and improve the allocation spread of food to agencies.

So far in this project, Operational Research (in this case specifically Linear Programming) appears to be a field that has much to offer to the humanitarian sector.

Most books and journals with publications on Operational Research imply that O.R. is a hard science that solves problems using strict models, mathematics and programs. (Ravn, 1986) In practice, though, O.R. may become a “softer”, social or voluntary process dealing with conflicting goals in the world. Some authors suggest that the utilization of O.R. methods might just be the answer to the radical changes that are so needed in the Third World. (Sims et al., 1982)

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APPENDIX A

INPUT TABLES

	OSTOCK	DONATS	LCLSTK	UCLSTK	PRRAND
BAKEDG	0	3612	0	0	5.80
CANNED	1631	731	0	20000	5.52
DAIRY0	0	3616	0	10000	4.09
DRYGOO	7164	19823	0	30000	4.24
EGGS00	0	424	0	0	14.60
FRUIT0	0	1774	0	0	3.96
RICEPA	0	0	0	20000	12.16
VEGETA	0	3674	0	0	4.41
BABYPR	512	388	0	10000	0
CEREAL	1798	1835	0	10000	0
COLDBE	792	3938	0	10000	0
CONDAM	625	1075	0	10000	0
DETERG	208	1651	0	10000	0
LUXURI	76	476	0	10000	0
SANDWI	0	0	0	10000	0
TOILET	0	858	0	10000	0

	LBAKEDG	UBAKEDG	LCANNED	UCANNED	LDAIRY0	UDAIRY0	LDRYGOO	UDAIRY0
BABYCA	0	0	0	0	2	2.4	0.2	0.24
FEEDIN	0.5	0.6	1	1.2	0	0	0.4	0.48
HEALTH	1	1.2	2	2.4	3	3.6	1	1.2
OLDAGE	1	1.2	2	2.4	3	3.6	0.8	0.96
YOUTH	1	1.2	2	2.4	4	4.8	1	1.2

LEGG00	UEGG00	LFRUIT0	UFRUIT0	LRICEPA	URICEPA	LVEGETA	UVEGETA
0.25	0.3	0.2	0.24	0	0	0.5	0.6
0	0	0.3	0.36	0.25	0.3	0.5	0.6
0.5	0.6	1	1.2	1	1.2	1	1.2
0.5	0.6	0.8	0.96	0.5	0.6	1	1.2
0.75	0.9	1	1.2	0.5	0.6	1	1.2

APPENDIX B

CODING

```
*OMNI,NUDD=BLD.DD,NULCU=BLD.LCU,NULST=BLD.LST
*   MODE,COMPILE
*   TITLE   FOODBANK
        COMPILE,ENDMARK=!
        DICTIONARY
        LIST,NEW PAGE
        DATA
*
        FORM SECTION
*
*   GENERATE ROWS SECTION OF THE MATRIX
*
        COPY
NAME           FBK
ROWS
        FORM ROW
                COST=OBJ
        FORM ROW
                (ROWNAM;M1-6)BAL=FIX   FOR ROWNAM = TABLE STOCKS(,1)
                (ROWNAM;M1-6)TOT=FIX   FOR ROWNAM = TABLE STOCKS(,1)
*
*   GENERATE VECTORS
*
        COPY
COLUMNS
        FORM SECTION,END
        FORM SECTION (ROWNAM)           FOR ROWNAM = TABLE STOCKS(,1)
        FORM VECTOR OS(ROWNAM;M1-6)
                (ROWNAM;M1-6)BAL=1
        FORM VECTOR DN(ROWNAM;M1-6)
                (ROWNAM;M1-6)BAL=1
        FORM VECTOR PR(ROWNAM;M1-6)
                (ROWNAM;M1-6)BAL=1
                COST=TABLE STOCKS(PRRAND,(ROWNAM))
```

```

FORM VECTOR AL(ROWNAM;M1-6) (RYNAAM;M1-6) FOR RYNAAM = TABLE AGENCY(,1)
    (ROWNAM;M1-6) BAL=-1
    (ROWNAM;M1-6) TOT=1
FORM VECTOR TOT(ROWNAM;M1-6)
    (ROWNAM;M1-6) TOT=-1
FORM VECTOR CS(ROWNAM;M1-6)
    (ROWNAM;M1-6) BAL=-1
    COST = 0.000001
FORM VECTOR EXTRA(ROWNAM;M1-6)
    (ROWNAM;M1-6) BAL=-1
    COST = 1

FORM SECTION,END (ROWNAM)
FORM SECTION

*
* GENERATE RIGHT HAND SIDES
COPY
RHS
FORM VECTOR RHS1
    COST=1

FORM CLASS BND
    UPX
    LOI
*
* GENERATE BOUNDS
COPY
BOUNDS
    FORM SECTION (ROWNAM)      FOR ROWNAM=TABLE STOCKS(,1)
    FORM BOUND BND
OS(ROWNAM;M1-6), (BND;M1-2)= TABLE STOCKS(OSTOCK,(ROWNAM))
DN(ROWNAM;M1-6), (BND;M1-2)= TABLE STOCKS(DONATS,(ROWNAM))
CS(ROWNAM;M1-6), (BND;M1-2)= TABLE STOCKS((BND;M1-1)CLSTK,(ROWNAM))
    FORM SECTION (RYNAAM)      FOR RYNAAM = TABLE AGENCY(,1)
    FORM SECTION (RRRROW)      FOR RRRROW = TABLE AGNTYP(,1)
                                WHEN (TABLE AGENCY((RRRROW),(RYNAAM))=1)

FORM VALUE

L(ROWNAM) (RYNAAM) =
    TABLE AGENCY(NOBNF,(RYNAAM)) * TABLE AGNTYP(L(ROWNAM),(RRRROW))
U(ROWNAM) (RYNAAM) =

```

```

TABLE AGENCY(NOBNF, (RYNAAM)) *TABLE AGNTYP(U(ROWNAM), (RRRROW))

FORM BOUND BND

AL(ROWNAM;M1-6) (RYNAAM;M1-6), (BND;M1-2) = N, (BND;M1-1) (ROWNAM) (RYNAAM)

FORM SECTION,END (ROWW)

FORM SECTION,END (RYNAAM)

FORM SECTION,END (ROWNAM)

FORM SECTION,END

ENDATA

END

LIST,EJECT

EXECUTE,ALL

* ENDJOB

SET,LCU=100

FORM SECTION

FORM VALUE

    MXLIN4NQ=0

FORM LINE

    V2=T,OSDATEC

SPACE

FORM LINE

    H6=FOOD BANK JOHANNESBURG.

FORM LINE

    H6=====

SPACE

FORM LINE                WHEN(N,STATUS.EQ.'OPTM')

    H6=OPTIMAL SOLUTION :

    H27=MINIMUM COST TO PURCHASE SHOTAGES (R):

    V75.2=Y,COST

SPACE

FORM LINE                WHEN(N,STATUS.EQ.'UNBD')

    H10=***** - PROBLEM UNBOUNDED - *****

FORM LINE                WHEN(N,STATUS.EQ.'INFE')

    H10=***** - PROBLEM INFEASIBLE - *****

SPACE

FORM LINE

    H6=SHORTAGE LIST

FORM LINE

    H6=====

SPACE

```

FORM LINE

H1=FOOD TYPE
H12=UNITS TO PURCHASE
H30=UNIT COST £
H45=TOTAL COST £
H60=OPENING STOCK
H80=DONATED TO FOODBANK
H105=DESPATCHED TO AGENCIES
H135=CLOSING STOCK
H158=EXTRA

FORM LINE

H1=-----
H12=-----
H30=-----
H45=-----
H60=-----
H80=-----
H105=-----
H135=-----
H158=-----

SPACE

FORM VALUE

TOTUNITS = 0
TOTPR=0

FORM SECTION (ROWNAM) FOR ROWNAM = TABLE STOCKS(,1)
* WHEN (X,PUR(ROWNAM;M1-6).NE.0)

FORM VALUE

TOTUNITS=N,TOTUNITS + X,PR(ROWNAM)

FORM VALUE

TOTPR=N,TOTPR+TABLE STOCKS(PRRAND,(ROWNAM;M1-6))*X,PR(ROWNAM;M1-6)

FORM LINE

D1=(ROWNAM;M1-6)
V22=X,PR(ROWNAM)
V36.2=TABLE STOCKS(PRRAND,(ROWNAM;M1-6))
V51.2=TABLE STOCKS(PRRAND,(ROWNAM;M1-6))*
 X,PR(ROWNAM;M1-6)
V70=X,OS(ROWNAM)
V90=X,DN(ROWNAM)
V118=X,TOT(ROWNAM)
V143=X,CS(ROWNAM)
V160=X,EXTRA(ROWNAM)

FORM SECTION, END (ROWNAM)

```

FORM LINE
H1=-----
H61=-----
H121=-----

FORM LINE
H1=TOTAL
* V25=N,TOTUNITS
V51.2=N,TOTPR

FORM LINE
H1=-----
H61=-----
H121=-----

FORM SECTION,END
FORM SECTION (RYNAAM) FOR RYNAAM = TABLE AGENCY(,1)
FORM SECTION (CLSAGN) WHEN ((RYNAAM)=(CLSAGN))

FORM LINE
H0=1
H2= AGENCY :
D11=(CLSAGN)H

FORM LINE
H1=-----
H61=-----
H121=-----

SPACE

FORM LINE
H1=FOOD TYPE
H19=UNITS TO BE DESPATCHED
H50=VALUE IN R

FORM LINE
H1=-----
H19=-----
H50=-----

SPACE

FORM VALUE
AGVAL=0
FORM SECTION (ROWNAM) FOR ROWNAM = TABLE STOCKS(,1)
* WHEN (X,AL(ROWNAM)(RYNAAM).NE.0)

FORM LINE
D1 = (ROWNAM;M1-6)
V29 = X,AL(ROWNAM)(RYNAAM)

```

```

V56.2 = X,AL(ROWNAM) (RYNAAM) *TABLE STOCKS(PRRAND, (ROWNAM) )
FORM VALUE
K      AGVAL=N,AGVAL + X,AL(ROWNAM) (RYNAAM) *TABLE STOCKS(PRRAND, (ROWNAM) )
FORM SECTION,END (ROWNAM)

FORM LINE
      H1=-----
      H61=-----
FORM LINE
      H1=TOTAL
      V56.2=N,AGVAL
FORM LINE
      H1=-----
      H61=-----
FORM SECTION, END (RYNAAM)
FORM SECTION,END (RYNAAM)
START
END
ENDJOB

```