Health Post Location and Resource Allocation Models for Community Oriented Primary Care

by

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Executive summary

Community oriented primary care or COPC is a health care delivery approach aimed at providing preventive care for a certain defined population. It is based on the principles of integrating social interventions and clinical care where the individual patient, family and the community are the focus of diagnosis and ongoing monitoring. The implementation of COPC is to be initiated by setting up health posts in seven sites in the Tshwane district. These health posts will serve as a community resource from where care workers can go into the community and perform the identified interventions based on a community health diagnosis. It is envisaged that the health posts will be used as training facilities for health science students and other faculties.

The location of the health posts and the allocation of resources to them pose challenges. The aim of this project is to develop models and conduct operational research that may be used in and beyond the Tshwane district. By considering criteria such as population density, geographical setting, community infrastructure and opportunity for growth, a location model will be developed. This model will assist the Department of Family Medicine to determine the optimal location for the health posts. To address the resource allocation problem, an operations research model may be developed to determine the optimal combination of finances, skills and experience needed at each health post.

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List of acronyms

AIDS	Acquired immune deficiency syndrome
CHD	Community health diagnosis
COPC	Community oriented primary care
DCM	Demand covered model
FPD	Foundation for Professional Development
GIS	Geographic information system
HCW	Health care worker
HIV	Human immunodeficiency virus
NGO	Non-governmental organisation
NSM	Number of sites model
OR	Operations research
PHC	Primary health care
SHC	Secondary health care
THC	Tertiary health care
TB	Tuberculosis

Chapter 1

Introduction

1.1 Introduction and background

The Department of Family Medicine of the University of Pretoria, in collaboration with the Tshwane health district office and the Foundation for Professional Development (FDP), is initiating the implementation of community oriented primary care (COPC). This will be done through the establishment of health posts in seven sites in the Tshwane district. These health posts will serve as community resources from where care workers can go into the community and perform the identified interventions based on a community health diagnosis (CHD). The health care workers (HCWs) will be responsible for providing holistic care to each household and giving feedback to a health post manager. It is envisaged that these health posts will be used as training facilities for health science students and other faculties.

The focus of this dissertation will be on the community of Mamelodi West, a suburb of the Tshwane Township, Mamelodi. Mamelodi is situated in the eastern part of the City of Tshwane Metropolis, Gauteng (Figure 1). It was established in June 1953 when 16 houses were built to house black citizens who were forcefully removed from different locations, according to the Group Areas Act (Mamelodi Township, 2011). Mamelodi was seen as a blacks-only area during the apartheid era and today has an estimated population of close to one million.

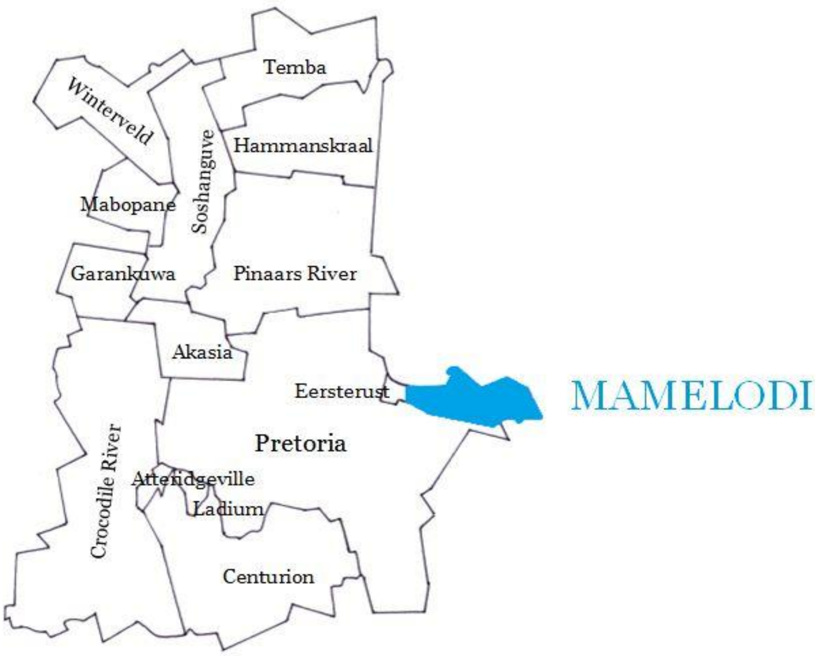

Figure 1 - Tshwane Metropolis, Gauteng. (Adapted from City of Tshwane, 2009)

Mamelodi West is situated in the western part of Mamelodi, adjacent to Watloo, Denneboom and Eerste Fabrieke (Figure 2). For a detailed map, drawn by Ingrid Booysen, refer to Appendix A.

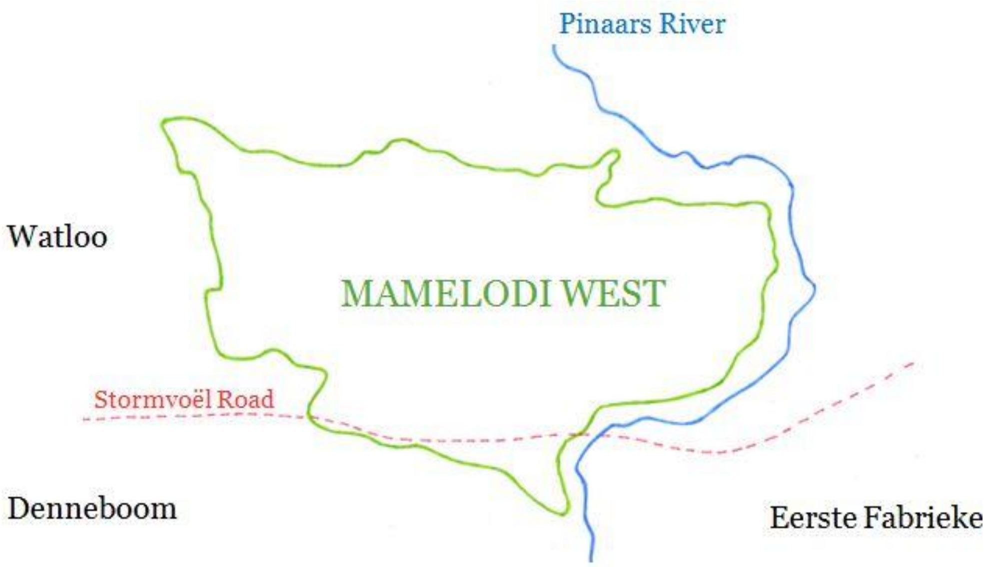

Figure 2 - Mamelodi West, Mamelodi (Adapted from map drawn by Ingrid Booysen)

The housing ranges dramatically from hostels and informal settlements to more established formal units (Nematsewari, 2011). These areas are illustrated and discussed in Figures 3 to 8. For explanatory reasons throughout the report, the areas are named Type A to F respectively.

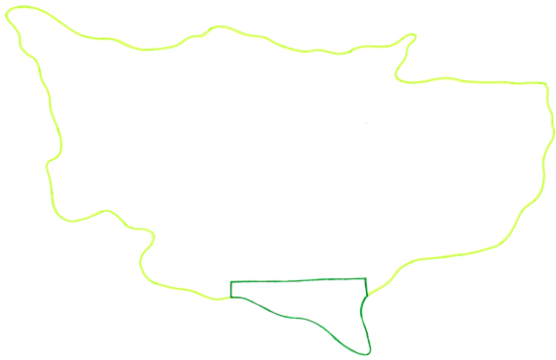

Figure 3 - Type A housing distribution

Type of housing: A

Description: formal units

# of residents per house: 3 to 5

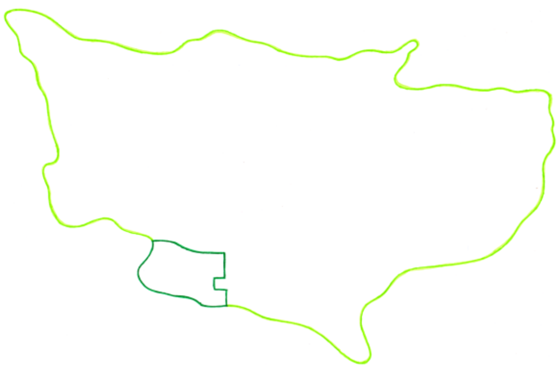

Figure 4 - Type B housing distribution

Type of housing: B

Description: hostels, apartment blocks

# of residents per house: 3 to 4

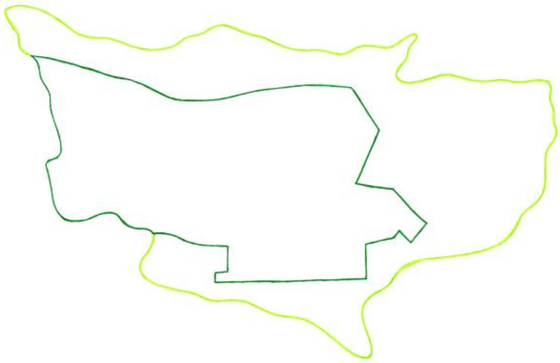

Figure 5 - Type C housing distribution

Type of housing: C

Description: informal settlement

# of residents per house: 7 to 12

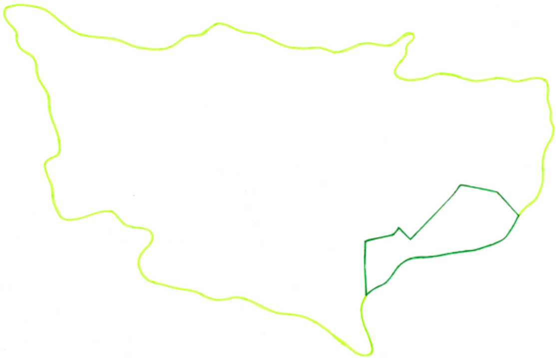

Figure 6 - Type D housing distribution

Type of housing: D

Description: formal units, governmental housing

# of residents per house: 4 to 6

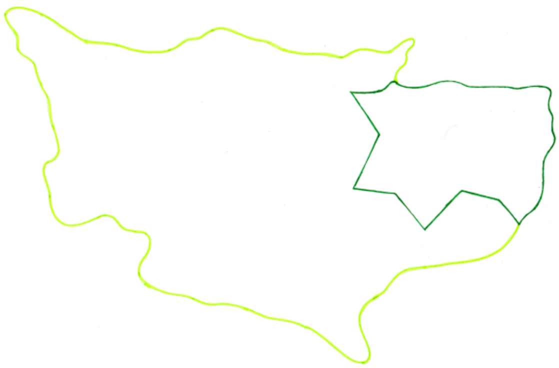

Figure 7- Type E housing distribution

Type of housing: E

Description: formal units, most recently developed area

# of residents per house: 4 to 6

Figure 8 - Type F housing distribution

Type of housing: F

Description: formal units, first formal units established

# of residents per house: 4 to 7

1.2 Problem statement

Cost and customer service are usually taken into account when locating facilities in the industry. When it comes to health care, the implications of locating health care centres incorrectly, stretch far beyond those considerations. If too few centres are placed or incorrectly positioned, it limits accessibility to services, thus increasing morbidity and mortality in the community.

Since the COPC health post programme is in its initial phase of development, the sites for locating the health posts have not yet been identified. Various factors such as population density, geographical setting, community infrastructure and opportunity for growth should be taken into account. Although a clinic is already functioning in Mamelodi West, its main shortcoming is its limited capacity and therefore its inability to treat all those who require medical attention. Some of the residents of Mamelodi West live beyond a 2 kilometre radius or an average of 20 minutes walking distance from the clinic, and are therefore at great risk if an emergency arises.

Furthermore, a health post can only be as efficient as its workers. The experience, competencies and skill levels of workers should therefore be balanced to ensure that residents of the community do not only have access to but also receive quality care. The available community health workers should be adequately dispersed among the chosen health posts.

1.3 Research design

The aim of this dissertation is to formulate a mathematical model for determining the optimal locations of health posts as well as allocating resources to these health posts in a rural community. The rationale for using mathematics to address the problem is supported by Eccles and Groth (2006: 2778)

> “Problems often impose demands that cannot be met given the natural human cognitive and physical limitations. One solution is to adapt oneself to the problem through training and practice, but when humans are unable or unwilling to adapt themselves, they often turn to adapting the environment, by creating technologies, to augment their problem-solving capabilities."

Hence mathematical modelling will be used to develop a suitable solution for the COPC health post programme. The models will provide a generic approach that can be used in similar communities with minimal adjustments and alterations needed.

1.4 Research methodology

The aim of this dissertation is to develop a health post location model and resource allocation model that may contribute to the COPC health post programme. The layout of the dissertation is as follows

Chapter 1 - Introduction: The introductory chapter elucidates the research topic and the problem to be addressed. The research design is also outlined.

Chapter 2 - Literature review: This chapter provides an overview of COPC, health conditions and health care. Different approaches and methodologies are also discussed and compared.

Chapter 3 - Model formulation: This chapter formulates a suitable solution to determine the optimal locations for health posts in a community as well as allocating resources to these health posts.

Chapter 4 - Data analysis: This chapter deals with the data used as inputs for both the models. The model results and sensitivity analyses are discussed in order to determine the functionality of the models.

Chapter 5 - Conclusions and recommendations: The last chapter concludes the dissertation and discusses possible future improvements to and development of the models.

1.5 Chapter summary

This chapter introduced and discussed the COPC health post programme and provided an overview of Mamelodi and Mamelodi West. The method used to design and conduct the research was also explained. The next chapter provides a detailed literature review on information relevant to the COPC health post programme and discusses the various methodologies.

Chapter 2

Literature review

2.1 An overview of COPC

COPC originated in South Africa as a government intervention to improve the health conditions of the country. In the 1940s, the founding members, Sidney and Emily Kark, developed the approach to enhance the primary health care system in Pholela, KwaZulu-Natal (Tollman & Pick, 2002). COPC was designed to address existing shortcomings in the health care system because at that time, the health needs of the community were not being met and the citizens did not reap the benefits of health care.

During the years that followed, apartheid placed a strain on the development of primary health care in South Africa because governmental funding for community outreach programmes was reduced and many of the founding members left the country (Kautzky & Tollman, 2009). It is during this time that the concept of COPC flourished overseas and even became a part of Cuba's National Policy and Standard of Health Care (Dresang, 2005).

When the political situation started to change in South Africa during the late 1980s and early 1990s, COPC was rediscovered as a suitable solution for the poor health care delivery in the country (Tollman & Pick, 2002). Today, COPC is seen as a primary health care approach that oversees the health of a certain defined population. It focuses on the health of families and the community, instead of on individual health alone. COPC is about integrating social involvement and medical care to reach the patients in the context of their homes for early detection, prevention, promotion of healthy lifestyles and home care.

The Department of Family Medicine in the Health Science Faculty of the University of Pretoria has defined the structural elements of COPC with the main stakeholders being the provinces, districts and local authorities. The Department of Health has the responsibility of being the primary driver of COPC with the other sectors assisting and contributing to the services (Hugo & Marcus, 2010). The structural elements are indicated in Figure 9, where services include private and public hospitals, the sectors of society are formed by NGOs and traditional healers and the sectors of government refer to social development.

Figure 9 - The structural elements of COPC (Adapted from Hugo & Marcus, 2010)

2.2 An overview of health care in South Africa

Health is viewed as one of the most important and essential needs of all people. It leads to the social wellbeing and productivity and growth of a nation. According to Professor Salman Rawaf, at the Imperial College of London, the health care system of any country has three ultimate goals, namely better health, responsiveness to people's needs and the financial protection against health care costs (Hugo & Marcus, 2010).

In a country with great diversity and beliefs, different forms of health care have taken shape over the years. A typical health care system in South Africa consists of three levels of care - primary, secondary and tertiary (Figure 10).

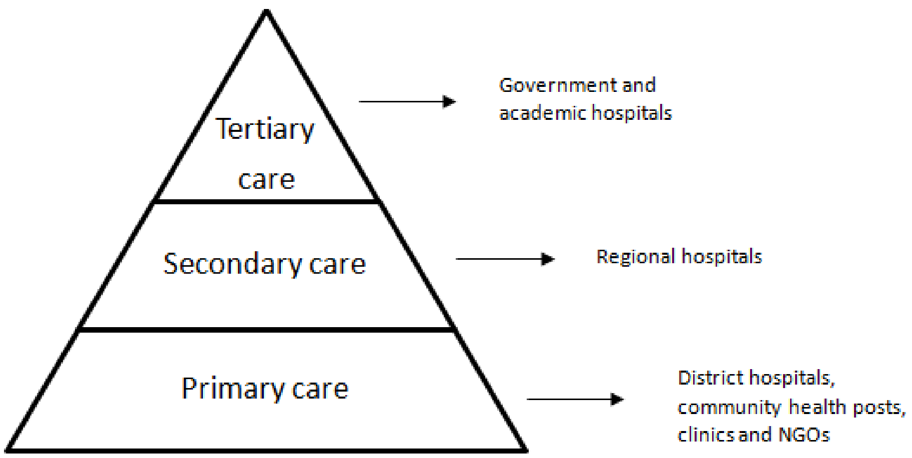

Figure 10 - The three levels of the health care system

2.2.1 Primary health care

Primary health care (PHC) plays a significant role in any country's health care system because it is the first contact a citizen has with the country's health care capabilities. PHC focuses on the principle of disease prevention, health promotion, minor ailments, palliative care and rehabilitation to the individual family and community.

2.2.2 Secondary health care

Secondary health care (SHC) is an intermediate level of health care that includes diagnosis and treatment, usually as a result of the referral from a primary or community health worker (Glanze & Anderson, 2009). Treatment at this level can either be elective or emergency care.

2.2.3 Tertiary health care

Tertiary health care (THC) is the last tier in the health care system and is a specialised, highly technical level of health care that includes the diagnosis and treatment of diseases and disabilities. Specialised intensive care units, advanced diagnostic support services and highly specialised personnel are usually characteristic of THC. It offers highly centralised care to the population of a large region (Glanze & Anderson, 2009).

2.2.4 Public and private health care

Health care can also be divided into two main categories, namely private and public health care. According to the White Paper for the Transformation of the Health System in South Africa, published in 2007, the activities of the public and private health sectors should be integrated in a manner that makes optimal use of all available health care resources. The public-private mix of health care should promote equity in service provision (Department of Health, 2007)

2.2.4.1 Public health care

The public health sector of South Africa covers roughly 80% of the population. It offers basic primary health care to those who cannot afford private medical care. This sector consumes around 11% of the government's total budget, which is allocated and spent by the nine provinces. The way in which these resources are allocated, and the standard of health care delivered, varies from province to province (Government, SA, 2010). The public sector is usually viewed as an area that is under-resourced and over-used.

2.2.4.2 Private health care

The private health sector offers specialised highly technical health services to those who can afford it. South African citizens who are covered by medical aid schemes and foreigners looking for top-quality procedures at a relatively affordable price are the main users of this sector (Government, SA, 2010). The private sector affords most health care professionals great opportunities and attracts most of the highly qualified personnel. Private hospitals focus on providing tertiary and specialised health care.

2.2.5 Health care difficulties

Apart from poverty-related illnesses, for a number of reasons, South Africa’s health care system is unable to meet the individual and population health care needs. According to the Department of Family Medicine in the Health Science Faculty of the University of Pretoria, the following add to the ongoing pressure placed on health care delivery (Hugo & Marcus, 2010):

- a lack of integration of health care services at clinic level and public dissatisfaction
- a hospital physician curative focus
- the inadequate health care provider-patient-community relationship
- passive and symptomatic health care services
- undervalued and insufficiently trained health care practitioners
- poor professional motivation and job satisfaction among service providers
- inadequate private and public sector health care integration

2.3 An overview of health conditions in South Africa

According to Coovadia, Jewkes and Barron (2009), South Africa faces four concurrent epidemics; poverty-related illnesses (perinatal and maternal diseases), non-communicable diseases (cancer), communicable disease (HIV/AIDS) and violence and injury among citizens. Some of the major challenges that South Africa faces is the ever-growing presence of TB, HIV/AIDS and malaria. Since these are some of the challenges facing Mamelodi West, they will be discussed in more detail. The mortality rate of mothers and children is also a huge concern (Kautzky & Tollman, 2009). These conditions have a profound effect on the daily lives of people living in rural communities.

2.3.1 Malaria

Malaria is caused by a parasite that is passed from one human to another by the bite of infected Anopheles mosquitoes. It can result in the destruction of blood cells, kidney and liver failure, meningitis, respiratory failure from fluid in the lungs and internal bleeding (A.D.A.M., 2011). Malaria can easily spread through a community because it can be transmitted from a mother to her unborn baby as well as through blood transfusions.

2.3.2 Tuberculosis

Tuberculosis (TB) is a chronic infectious disease that usually affects the lungs. TB is mainly spread when a person infected with TB coughs or sneezes, and the recipient breathes in the airborne bacteria (Health24, 2011). Hence in areas such as rural communities where residents live in close proximity, TB can result in the health deterioration of the entire community. It is a curable disease but requires an unbroken six-month treatment period, and if the treatment is stopped before the end of six months, it may result in the emergence of drug-resistant strains of TB. South Africa has a particularly high rate of TB sufferers because it is a common infection among HIV-positive people (WHO, 2010).

2.3.3 HIV/AIDS

South Africa has the highest levels of HIV and AIDS in the world, with young adults between the ages of 25 and 49 being the most affected. HIV is transmitted from one person to another through the exchange of bodily fluid. In South Africa, the main form of transmission is that of an infected mother to her unborn child. This results in the HIV-infected child being born into a household that has already taken strain under the virus in terms of health, income, productivity and the ability to care for one another (Avert, 2011). The HIV virus also poses a threat for the health workers who treat the HIV-infected patients because infection can easily be spread (Shisana, Hall, Maluleke, Chauveau, & Schwabe, 2004).

2.4 Existing models

A number of works have been published that deal with the different methods of locating facilities in a certain area as well as allocating resources to them. A favourable solution to these problems is the use of mathematical programming methods such as operations research (OR). According to Winston and Venkataramanan (2003), OR is a scientific approach to decision making that seeks the best design for operating a system, usually under conditions requiring the allocation of scarce resources.

OR can be used to find a solution to the challenges experienced in the COPC health post programme. COPC involves the use of limited funds and deals with the allocation of scarce resources caused by shortages in the number of available workers. OR enables one to achieve a balance between finance, skills level and experience.

2.4.1 Location model methodology

When studying optimal location models, three focal points come to mind, namely accessibility, adaptability and availability (Daskin & Dean, 2004). The most frequently used location model in OR is the set covering model. This model is used to minimise the cost of locating facilities such as factories, warehouses or clinics in a region and also deals with minimising the number of locations required.

2.4.1.1 Set covering model

In the work, *Operations research and health care: a handbook of methods and applications* (Daskin & Dean, 2004), a set covering model was formulated that serves as a basic location model. This model may then be adjusted and altered to include different constraints and considerations based on the needs of the current project.

The set covering model formulated by Daskin and Dean (2004) is as follows:

I = Set of demand nodes
J = Set of candidate facility sites

$$a_{ij} = \begin{cases} 1 & \text{if demand node i can be covered by a facility at candidate site j} \\ 0 & \text{if not} \end{cases}$$

$$x_j = \begin{cases} 1 & \text{if we locate at candidate site j} \\ 0 & \text{if not} \end{cases}$$

$f_j =$ fixed cost of locating a facility at candidate site j

$$\text{Min } Z = \sum_{j \in J} f_j x_j \qquad (2.1)$$

s.t.

$$\sum_{j \in J} a_{ij} x_j = 1 \qquad \forall \qquad i \in I \qquad (2.2)$$

$$x_j \in \{0,1\} \qquad \forall \qquad j \in J \qquad (2.3)$$

The objective function (2.1) minimises the total cost of all the selected facilities. Constraint (2.2) ensures that each demand node is covered by at least one of the selected candidate facilities. Constraint (2.3) is viewed as a standard operations research condition.

2.4.2 Resource allocation methodology

When developing resource allocation models, different factors should be taken into account such as reduced efficiency because of absenteeism, lack of job satisfaction, formal grievances and generally deteriorating labour relations (Eiselt & Marianov, 2006). The most common method to allocate resources in OR is to build a dynamic work scheduling model (Winston & Venkataramanan, 2003). This model is used to minimise the number of workers needed, taking into account fair labour practices. Using this model it is possible to calculate how many workers are required in an area as well as what schedule they will follow.

According to Humphreys (1998), resource allocation decisions for health care planning have moved away from traditional funding mechanisms. He believes that more people are currently making use of needs-based formulae. He (1998) contends that by using this approach, the allocation of resources should reflect more closely the population characteristics and health needs of residents in a community.

2.5 Alternative methodology

Instead of using operation research methodology to determine the location of facilities, different methods such as the geographic information system and the weighted average method could also have been chosen. An alternative operation research methodology, the nurse rostering problem, may be considered for the resource allocation problem (Du Plessis, 2010).

2.5.1 Geographic information system

The geographic information system (GIS) integrates hardware, software and data for capturing, managing, analysing and displaying all forms of geographically referenced information. It allows the user to view, understand, question, interpret and visualise data in many ways that reveal relationships, patterns and trends in the form of maps, globes, reports and charts (What is GIS?, 2011).

In 2006, Tanser, Gijsbersen and Herbst (2006) developed a GIS to determine health care accessibility and utilisation. The study was conducted in Hlabisa, a rural district of Umkhanyakude in Northern KwaZulu-Natal. The researchers (2006) validated GIS as a rational and cost-effective health service planning and resource allocation method in developing countries.

With reference to the research problem in this dissertation, GIS may be used to take into account the relationships between the possible health post locations and the households in Mamelodi West. It may be used to determine a more accurate distance between the sites and the households. However, because of limited time and a lack of experience with GIS, this method was deemed unsuitable for the purpose of this dissertation.

2.5.2 Weighted average method

The weighted average method works on the principle of proportionally assigning numerical values or weights to factors based on their degree of importance (Tomkins, White, Bozer, & Tanchoco, 2010). Weighted averages are used extensively in descriptive statistical analysis (Weighted Averages, 2010) and can therefore be used in location models to distinguish the significance of one location above another.

With reference to the research problem in this dissertation, the weighted average method may be used to take in account the households demands as well as the individual distance from the household to the possible site. To determine the individual distances, it would have been necessary to conduct an in-depth study to determine the geographical layout of Mamelodi West. However, because of time restraints and limited data, this method was deemed unsuitable for the purpose of this dissertation.

2.5.3 Nurse rostering problem

Burke (1999: 189) describes the nurse rostering problem (NRP) as follows: “The assignment of duties to a set of people with different qualifications, work regulations and preferences”. The model determines the working hours and shift requirements of the nurses. NRP is regarded as a complex model that takes several constraints into account. These constraints should be met in order for the model to be considered feasible (Du Plessis, 2010).

With reference to the research problem in this dissertation, the NRP may be used to determine how many HCWs are needed and which households are allocated to them. However, the HCWs who are appointed at the health posts are not appointed on a shift basis. They work five days a week, six hours a day, during which time they visit the households on the basis of a specific household's importance. This importance may change weekly, even daily, and owing to time constraints and a lack of available data, this method was deemed unsuitable for the purpose of this dissertation.

2.6 Sensitivity analysis

Sensitivity analysis can be defined as the process of changing key model inputs to determine their effect on the outputs (Evans, 2010). The importance of sensitivity analysis becomes clear when working with forecasted or budgeted values. Because changes in economic and environmental sectors are inevitable, the optimal solution identified through operations research may no longer be feasible and these changes should therefore be incorporated into the final design.

2.7 Chapter summary

This chapter provided an overview of COPC, health conditions and health care in South Africa. Different approaches to and methodologies for location and resource allocation were discussed and compared. In the next chapter, these methodologies will be used to formulate a suitable solution to the COPC health post problem.

Chapter 3

Model formulation

In this chapter, the set covering model developed by Daskin and Dean (2004) is used to formulate a suitable health post location model. As discussed in the literature review, a set covering model is concerned with identifying the optimal location of facilities on the basis of factors such as space availability and set-up cost.

3.1 Health post allocation model for COPC

The health post allocation model may be broken down into two separate models that will be used in unison to determine the ultimate location of the health posts. Even though both models have the same end purpose of identifying the optimal locations for the health posts, the data on which they base their decision differ. The first model identifies the possible locations while focusing on covering all the households in the community. The second model, however, focuses on covering the households that present the highest demand in number of residents in a minimum number of households. Hence, depending on the decision maker's point of focus, both models can serve as a guideline to help determine the health post locations. For the purpose of this dissertation, each model was assigned a unique name. The first model, which is discussed in 3.1.1, will be referred to as the number of sites model or NSM. The second model, which is discussed in 3.2.2, will be referred to as the demand covered model or DCM.

3.1.1 Number of sites model (NSM)

One of the major factors in the COPC health post programme is the availability of funds. Because this is a public health initiative, the health posts should be located in such a way that they minimise the costs incurred. To keep the cost of the programme as low as possible, sites already owned by the government, such as schools, will be used as initial health post locations. As the programme expands and more funding becomes available, additional ground can be purchased.

However, unavoidable operating costs such as the wages of the health workers and medical supplies will increase with each health post located. Therefore, in order to reduce the costs of the programme the number of sites chosen to locate these health posts should be minimised.

The sets, variables and parameters that will be used in the model and constraints are set out below.

Sets

I = Set of possible health post sites
J = Set of demand nodes to cover

Decision variables

$$s_i = \begin{cases} 1 & \text{if health post is located at site i, where } i \in I \\ 0 & \text{otherwise} \end{cases}$$

$$p_{ij} = \begin{cases} 1 & \text{if health post can cover demand node j, where } i \in I \text{ and } j \in J \\ 0 & \text{otherwise} \end{cases}$$

Parameters

a_i □ the x co-ordinates of site i, where $i \in I$
b_i □ the y co-ordinates of site i, where $i \in I$
c_j □ the x co-ordinates of demand node j, where $j \in J$
d_j □ the y co-ordinates of demand node j, where $j \in J$
h_{ij} □ the calculated distance between site i and demand node j, where $i \in I$ and $j \in J$
K □ the allowable distance between site i and demand node j, where $i \in I$ and $j \in J$

The NSM can be formulated as follows:

$$\text{Min } Z = \sum_{i \in I} s_i \qquad (3.1)$$

s.t.

$$h_{ij} = |c_j - a_i| + |d_j - b_i| \qquad \forall \quad i \in I, j \in J \qquad (3.2)$$

$$\begin{aligned} &\text{if } h_{ij} \leq K \text{ then } p_{ij} = 1 \\ &\quad h_{ij} > K \text{ then } p_{ij} = 0 \qquad \forall \quad j \in J \end{aligned} \qquad (3.3)$$

$$\sum_{i \in I} p_{ij} s_i \geq 1 \qquad \forall \quad j \in J \qquad (3.4)$$

$$s_i \in \{0,1\} \qquad \forall \quad i \in I \qquad (3.5)$$

The objective function (3.1) of the linear programming model is used to minimise the total number of sites needed to be able to cover all of the demand nodes. In (3.2) the distance between the possible site and the demand node to be covered is calculated. Constraint (3.3) states that if the distance between the site and the node is less than or equal to the allowable walking distance, the demand node can be covered by the particular site. If the distance is more than the allowable walking distance, the demand node cannot be covered by the particular site. Constraint (3.4) guarantees that every demand node is covered by at least one of the sites. Constraint (3.5) ensures that s_i can only be 1 or 0.

3.1.2 Demand covered model (DCM)

After the minimum number of locations required for covering all the demand nodes have been identified, the DCM will further reduce the number by focusing on covering the demand nodes that present the highest demand. In this model, the total number of health posts that should be located is an input and results in the optimal locations for these health posts.

The sets, variables and parameters, which will be used in the model, as well as the constraints, are described below.

Sets

I = Set of possible health post sites
J = Set of demand nodes to cover

Decision variable

$$s_i = \begin{cases} 1 & \text{if health post is located at site i, where } i \in I \\ 0 & \text{otherwise} \end{cases}$$

$$n_j = \begin{cases} 1 & \text{if demand node j is coverd, } j \in J \\ 0 & \text{otherwise} \end{cases}$$

$$p_{ij} = \begin{cases} 1 & \text{if health post can cover demand node j, where } i \in I \text{ and } j \in J \\ 0 & \text{otherwise} \end{cases}$$

Parameters

a_i □ the x co-ordinates of site i, where $i \in I$
b_i □ the y co-ordinates of site i, where $i \in I$
c_j □ the x co-ordinates of demand node j, where $j \in J$
d_j □ the y co-ordinates of demand node j, where $j \in J$
h_{ij} □ the calculated distance between site i and demand node j, where $i \in I$ and $j \in J$
g_j □ the total demand of demand node j, $j \in J$
K□ the allowable distance between site i and demand node j, where $i \in I$ and $j \in J$
T□ the total number of health posts to locate

The DCM can be formulated as follows:

$$\text{Max } Z = \sum_{j \in J} g_j n_j \tag{3.6}$$

s.t.

$$h_{ij} = |c_j - a_i| + |d_j - b_i| \qquad \forall \quad i \in I, j \in J \tag{3.7}$$

$$\begin{aligned} &\text{if } h_{ij} \leq K \text{ then } p_{ij} = 1 \\ &\quad h_{ij} > K \text{ then } p_{ij} = 0 \qquad \forall \quad j \in J \end{aligned} \tag{3.8}$$

$$n_j - \sum_{i \in I} p_{ij} s_i \leq 0 \qquad \forall \quad j \in J \tag{3.9}$$

$$\sum_{i \in I} s_i = T \tag{3.10}$$

$$s_i \in \{0,1\} \qquad \forall \quad i \in I \tag{3.11}$$

$$n_j \in \{0,1\} \qquad \forall \quad j \in J \tag{3.12}$$

The objective function (3.6) maximises the number of demand points covered. In (3.7), the distance between the possible site and the demand node to be covered is calculated. Constraint (3.8) states that if the distance between the site and the node is less than or equal to the allowable walking distance, the demand node can be covered by the particular site. If the distance is more than the allowable walking distance, the demand node cannot be covered by the particular site. Constraint (3.9) states that a demand node cannot be counted unless a site is located to cover it. Constraint

(3.10) guarantees that the correct number of sites will be located. Constraints (3.11) and (3.12) ensure that s_i and n_j can only be 1 or 0.

3.1.3 Model alterations

The set covering model developed by Daskin and Dean (2004) was altered to include the conditions and constraints identified by the COPC health post programme. These alterations include limiting the walking distance of the HCWs between the health post site and the demand nodes as well as placing specific emphasis on the demand that each node presents.

3.2 Resource allocation model for COPC

The resource allocation model is developed to determine the number of HCWs who should be appointed at each of the health posts. The demand nodes that each health post covers as well as the available time a worker has per day is taken into account. Microsoft Excel 2007 was used to determine the number of health workers. Allocating a household to a specific HCW was done manually.

At each health post, a health post manager will be appointed. The manager will be responsible for all the administrative requirements of the post, reporting to the Department of Family Medicine as well as appointing and allocating HCWs. It is for this reason that the program, Microsoft Excel, was used to determine the number of HCWs, because it is generally easy to master. LINGO, a mathematical modelling program, requires intense training, and the health post manager will therefore not necessarily be capable of using the model for its intended purpose. With a Microsoft Excel model, the manager will be able to change and monitor the HCWs as well as the households allocated to them without requiring any assistance.

The HCW needs to report to the health post manager once a day. However, it does not necessarily have to be at a specific time of the day. The HCWs may thus choose to visit the households closest to their own homes at the end of the day, on their way to home, and only report the non-important information the following day. This can improve the workers morale and performance. Hence, if the households are manually allocated, it may be possible to accommodate the HCWs around this matter. Once again, if the households are manually allocated instead of using mathematical programming, the health post manager will be able to change and monitor the HCWs without needing assistance.

The sets, variables and parameters, which will be used in the model, are described below:

Sets

J = The demand nodes that are allocated to the specific health post

Parameters

N_j = The number of households in demand node j, where $j \in J$
T_j = The average walking time from the health post to demand node j, where $j \in J$
C = The number of households that may be allocated to an HCW
K = The time that an HCW works per day
A_j = The time an HCW has available for visiting the households in demand node j after the walking time has be substracted, where $j \in J$

Decision variables

H_j = The number of households that the HCW will be able to cover in demand node j, where $j \in J$
W_j = The number of HCWs to appoint in demand node j, where $j \in J$

The resource allocation model can be formulated as follows:

Demand node	# of Households per node (N_j)	Walking time from health post to node (T_j)	Available time left for visiting (A_j)	# of Households per HCW (H_j)	# of HCWs per node (W_j)
= J(1)	$= N_1$	$= T_1$	$= K - 2*T_1$	$= (A_i /K)*C$	$= N_1 / H_1$
= J(2)	$= N_2$	$= T_2$	$= K - 2*T_2$	$= (A_2 /K)*C$	$= N_2 / H_2$
= J(3)	$= N_3$	$= T_3$	$= K - 2*T_3$	$= (A_3 /K)*C$	$= N_3 / H_3$
:	:	:	:	:	:
= J(n)	$= N_n$	$= T_n$	$= K - 2*T_n$	$= (A_n /K)*C$	$= N_n / H_n$
The number of HCWs to allocate to the health post:					$=ROUNDUP(SUM(W_1:W_n))$

Table 1 - Resource allocation model as developed in Excel

After the number of HCWs per health post has been determined, each household in the demand node is allocated to a specific worker. This is to ensure that an HCW is responsible for a specific household's coverage. However, because the demand and distances of each node differ, this step is done manually. Based on $H_{j,}$ which is the number of households that an HCW can cover in a demand node, each worker is allocated his or her specific households.

3.3 Chapter summary

The alterations made to the initial set covering model allow for a suitable solution to determine the locations of health posts in a community. The resource allocation model determines how many HCWs should be allocated to each health post. From this model, the households can be allocated to specific HCWs. The next chapter will discuss the data used as inputs for both the models, and this will be followed by the model results and sensitivity analyses to determine the functionality of the models.

Chapter 4

Data analysis

This chapter discusses the data used as inputs for the health post location models and the resource allocation model, and this is followed by an explanation of the model results and sensitivity analyses to determine the functionality of the models.

4.1 Health post location model

This section describes the results for both the health post location models. The models were programmed in LINGO, version 8.0, using a standard personal computer. The NSM was solved in under three seconds and had a total of 27 integers, 58 constraints and eight iterations. The DCM model was solved instantly. The model had a total of 62 integers, 59 constraints and 107 iterations. The detailed LINGO models can be viewed in Appendices D and E respectively. The relevant sets and parameters used in the model formulation will now be discussed, followed by the results and the sensitivity analyses of the models.

4.1.1 Number of sites model

4.1.1.1 Pre-processing procedure

The inputs used in the NSM were group into defined sets. The decision variables and parameter values were determined from these sets.

Sets

Two sets were constructed for the NSM. Set I is defined by listing the possible sites that may be used for the location of the health posts. Twenty-seven possible sites were identified and Table B.1 in Appendix B provides a list of these sites together with their relevant information. Set J, containing all the demand nodes that should be covered by the health posts, was methodically determined by placing a grid over the map of Mamelodi West, as indicated in Figure 11. Each block in the grid represents a 400 m x 400 m area of land and contains the households that should be covered by the health posts. The number of households differs for each block, but for the NSM, only the number of blocks (i.e. nodes) were used. Fifty-seven nodes were identified. A detailed map with the grid, drawn by Ingrid Booysen, can be seen in Appendix A.

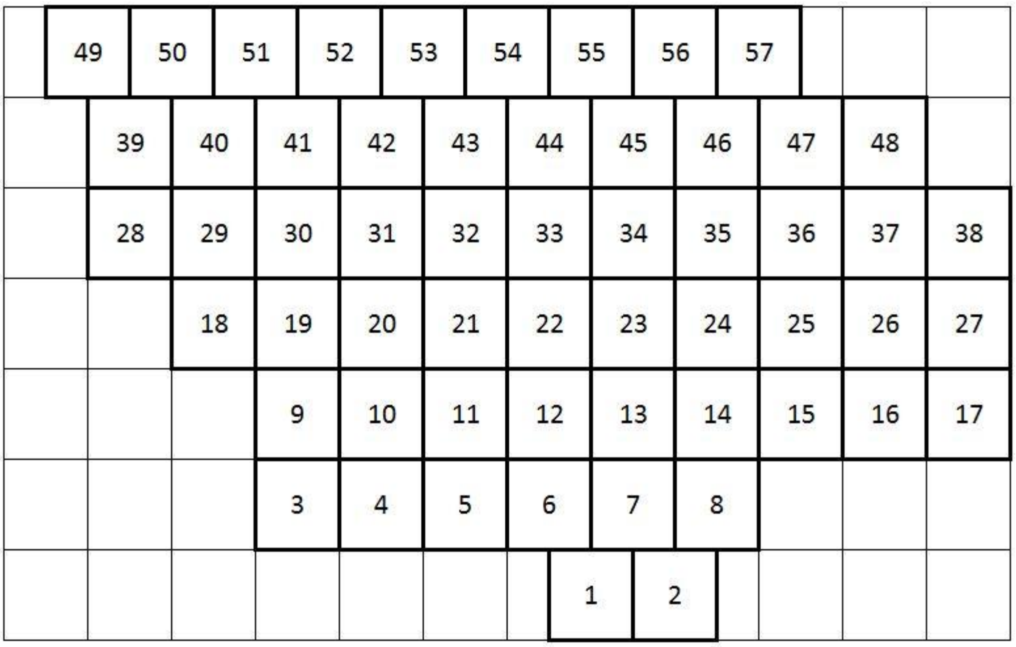

Figure 11 - Grid placed over Mamelodi West

If the possible health post sites are added to the grid, the sets used in the NSM can be depicted as follows. The numbers indicate the number of possible sites per block:

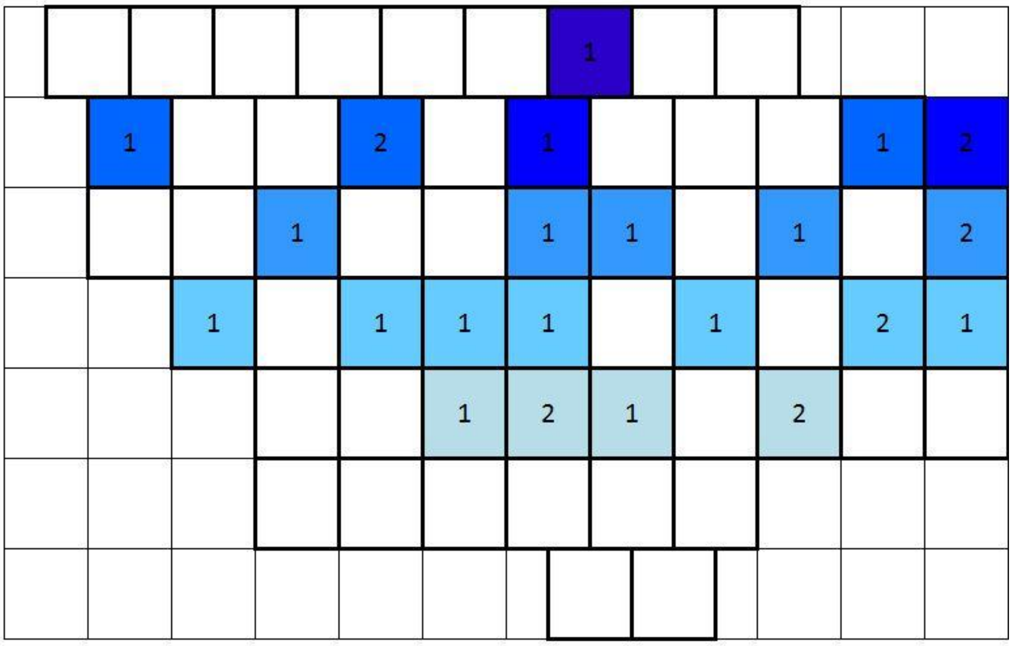

Figure 12 - Locations of possible health post sites

Parameters

With reference to the sets, h_{ij} is the calculated distance from the possible health post site i to the demand node j. In order to do this, the grid used to identify the demand nodes served as an x-y axis, as depicted in Figure 13. The x values ranges from 0 to 12 and the y values from 0 to 7, where each increment represents 400 metres to scale.

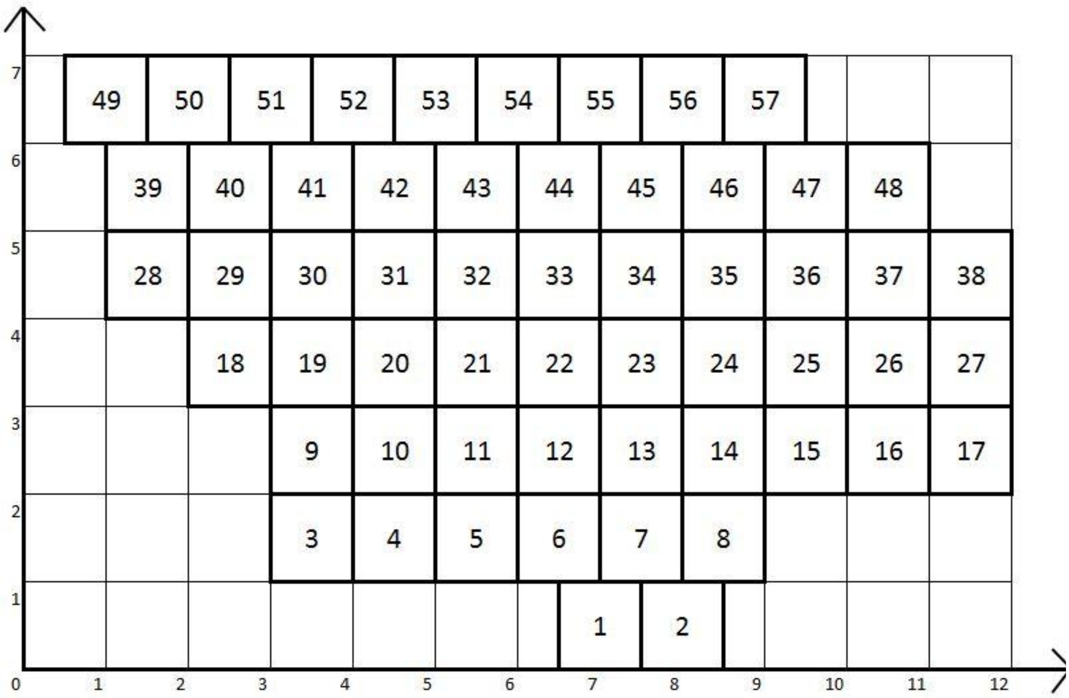

Figure 13 – The x-y axis of the grid placed over map of Mamelodi West

From this axis, the x and y co-ordinates of both the possible sites and the demand nodes were determined. The x and y co-ordinates of the possible sites are represented by a_i and b_i respectively and they represent the physical position of the sites in the grid. However, because the household scattering differs for each demand node, the co-ordinates of the demand nodes are regarded as the middle point of each block. This is done to ensure an equal variance in distance from the node to all the possible sites. The co-ordinates of the demand nodes are represented by c_j and d_j respectively. The rectilinear distance between the possible site and the demand node is calculated because this gives a realistic representation of the routes that will be followed by the HCW. A detailed list of the x and y co-ordinates for the possible sites and demand nodes is provided in Tables B.2 and B.3 in Appendix B.

The allowable distance between the sites and the nodes corresponds to the parameter K. The distance that an HCW travels from a health post to a household may not exceed a walking time of roughly 15 minutes. The average human being walks at a rate of 5 kilometres per hour. It can therefore be assumed that an HCW can travel 1.25 kilometres in 15 minutes. If this is converted to the scaled grid and some allowance is added for variances in travelling speed, K may be seen as being equal to 3.2 units.

4.1.1.2 Model results

The objective of the NSM is to minimise the number of health posts that should be located in Mamelodi West in order to cover all the residents. If the walking distance of the HCW is kept at 1.25 kilometres or 3.2 units, as determined in the parameters, the model minimises the 27 possible sites to five possible sites. These five sites are able to cover all the demand nodes. Figure 14 illustrates where these sites are located and which demand nodes each site is able to cover. The nodes containing more than one colour indicate that more than one site is capable of covering it. A list of the resulting five sites is provided in Table 2.

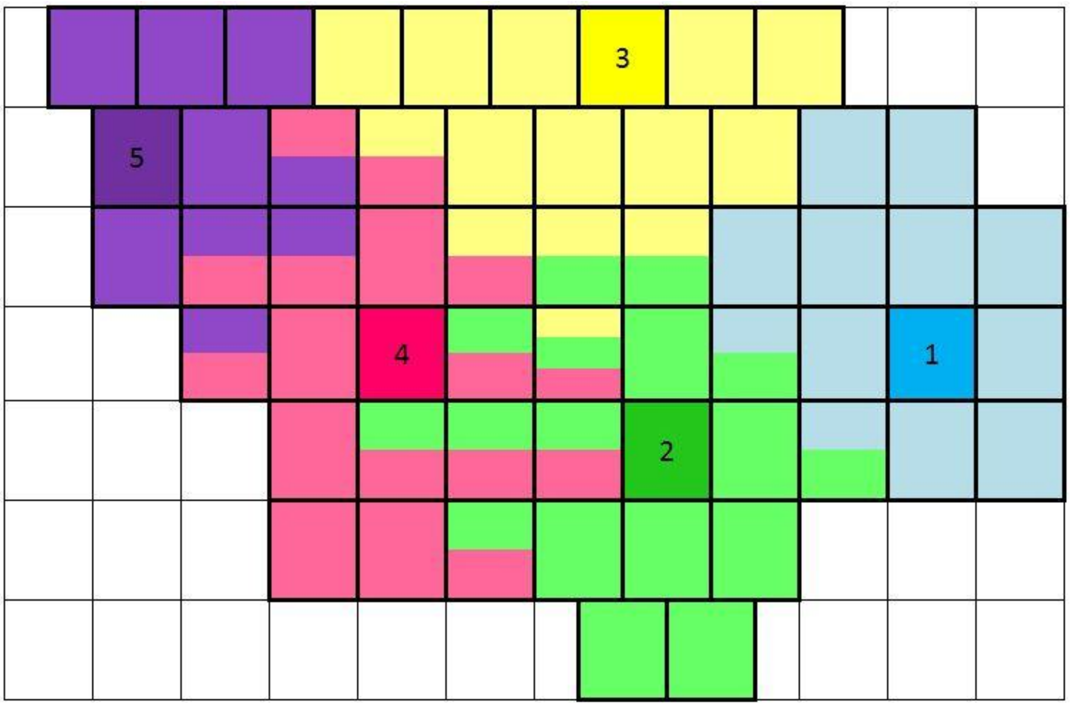

Figure 14 - Location of possible sites and the demand each site covers

Site #	Name
1	Vulcani Mawethu Secondary School
2	Ezazi Primary School
3	Tshimollo Primary School
4	Bohlabatsatsi Primary School
5	Shirinda Primary School

Table 2 - The resulting five possible health post sites

4.1.1.3 Model validation through sensitivity analysis

The model was tested by increasing and decreasing the allowable walking distance, K, of the HCW to determine what the effect would be on the objective value. If the distance is less than 1.1 kilometres, the model is unfeasible. As the distance increases, the model becomes feasible, and a different number of sites are chosen as possible solutions. This is indicated in Table 3.

Walking distance, K, in km	Walking distance scaled to grid	# of sites
K ≤ 1.1	K ≤ 2.75	Unfeasible
1.1 < K ≤ 1.54	2.75 < K ≤ 3.85	5
K = 1.25	**K = 3.2**	**5**
1.55 < K ≤ 1.56	3.85 < K ≤ 3.9	4
1.56 < K ≤ 1.92	3.9 < K ≤ 4.8	3
1.92 < K ≤ 2.92	4.8 < K ≤ 7.3	2
K > 2.92	K > 7.3	1

Table 3 - The results from changing the allowable walking distance

An examination of the feasibility of the model and taking into account the allowable walking distance, defined in the parameters, indicate that the best solution would be to locate five health posts.

4.1.2 Demand covered model

4.1.2.1 Pre-processing procedure

The inputs used in the DCM were group into defined sets. The decision variables and parameter values were determined from these sets. Since this model uses the results from the NSM as inputs, a number of similarities are evident between the two models.

Sets

The same sets that were identified in NSM are used in the DCM, where set I represents the possible health post sites and set J the demand nodes that should be covered. However, set I now consists only of the five health post sites identified in the NSM. These sites are indicated in Table C.1 in Appendix C. Set J consists of all 57 of the demand nodes as identified in the NSM.

Parameters

With reference to the newly defined sets, the following parameters for DCM remain the same as those for the NSM: h_{ij}, a_i, b_i, c_j, d_j and K. The parameter g_j represents the number of people living in each of the demand nodes and can therefore be regarded as the demand of each demand node.

This demand is determined by counting the number of households per demand node and adding the number of residents in each household. Hence the demand of each demand node can be seen either as the number of households or as the number of residents per demand node. For the DCM model, the demand will be equal to the number of residents per demand node.

However, as discussed in Chapter 1, the number of residents per household differs depending on the area in which the house is located. In a community such as Mamelodi West, which contains informal settlements and is characterized by the continuous relocation of residents, the South African National Census performed in 2001 can no longer represent accurate data of house occupancy. An estimated number of residents per household may thus be determined on the basis of possible upper and lower limits. A random generator is used to produce an individual number of residents for each household, depending on the population density of the area. Microsoft Excel 2007 was used as the random generator, and in Table 4, demand node 55 was used to illustrate how the demands were calculated. The resulting demands of all the demand nodes are indicated in Table C.2 in Appendix C.

Demand node:	55
Type of housing:	Formal units, 4-7 residents per house
# of houses per node:	18

House number	Number of residents per house: = RANDBETWEEN(4,7)
1	6
2	6
3	5
4	4
5	4
6	4
7	6
8	5
9	4
10	4
11	7
12	4
13	5
14	4
15	5
16	6
17	7
18	4
Total demand per node:	90

Table 4 - The demand calculations of demand node 55

Parameter T is the number of health posts that may be located at the beginning of the health post programme. Although the NSM determined that five health posts should be located in the area, this is as yet not financially feasible. As the programme grows and more funding becomes available, all the health posts identified by the NSM could be located. The Department of Family Medicine decided that a health post should be located for every 3 000 to 3 500 households. There are currently 10 659 households in Mamelodi West, as indicated in Table C.2 in Appendix C. Using the upper limit of households and dividing 10 659 by 3 500, it is evident that three health post should initially be located. Hence T is equal to three households.

4.1.2.2 Model results

The objective of the DCM model is to maximise the number of residents who can be covered if only three of the five sites identified in the NSM are located. The model therefore takes into account the demand that each demand node offers and identifies the three best sites to use for the health post locations. These three sites are depicted in Figure 15. A list of the resulting three sites is indicated in Table 5.

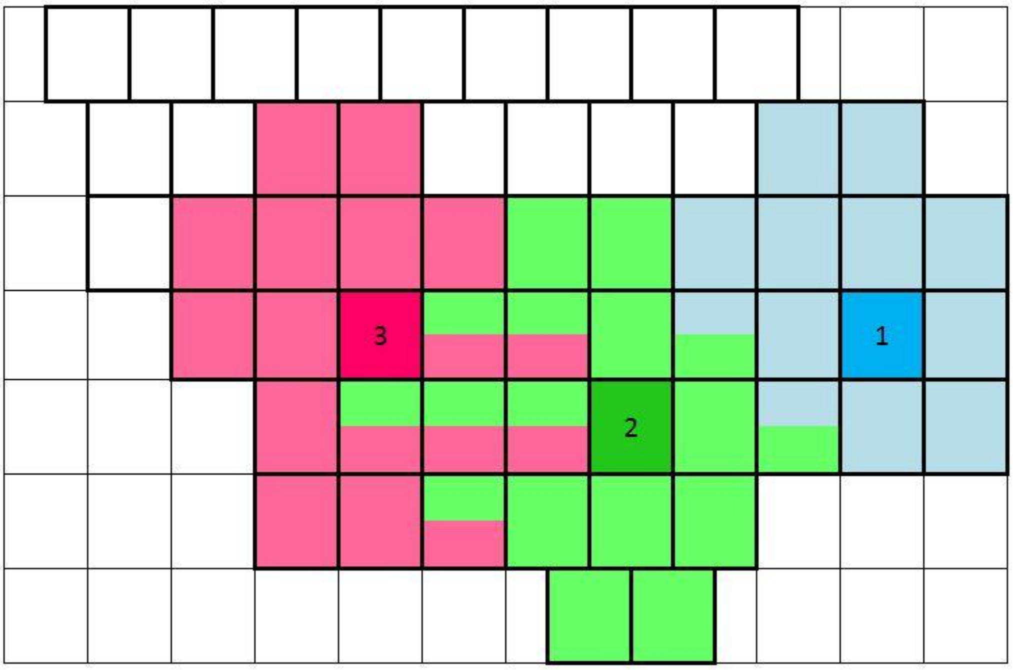

Figure 15 - The resulting three health post sites and the demand nodes they cover

Site #	Name
1	Vulcani Mawethu Secondary School
2	Ezazi Primary School
3	Bohlabatsatsi Primary School

Table 5 - The resulting three health post sites

4.1.2.3 Model validation through sensitivity analysis

The model was tested by increasing and decreasing the number of sites that may be located. This was done to verify that as additional sites are located, the previously selected sites remain the same. This ensures that the model does not choose the three sites without taking the demand into account. The resulting sites that are identified are indicated in Table 6.

# of sites located	The chosen locations					Demand covered (in residents)
	Site 1	Site 2	Site 3	Site 4	Site 5	
1	-	-	-	X	-	31 965
2	-	X	-	X	-	45 434
3	X	X	-	X	-	54 534
4	X	X	X	X	-	61 027
5	X	X	X	X	X	66 734

Table 6 - The results from increasing and decreasing the number of sites

It is evident that if only one site is located, Site 4 would be the best option because it is capable of covering 31 965 of the residents. Site 2 should then be added and together they are capable of covering 45 343 of the residents. Site 1, Site 3 and Site 5 are added in a similar fashion as the number of sites is increased. Hence the three sites that should be chosen to maximise the number of residents that can be covered are Site 1, Site 2 and Site 4.

4.2 Resource allocation model

This section describes the results for the resource allocation model. The model was developed using Microsoft Excel 2007, using a standard personal computer. The relevant sets and parameters used in the model formulation, as well as the results of the model, will now be discussed.

4.2.1 Pre-processing procedure

The inputs used in the NSM were grouped into a defined set. The decision variables and parameter values were determined from this set.

Set

Set J contains the demand nodes that are allocated to a health post. As indicated in Figure 15, some nodes are covered by more than one health post, it is therefore necessary to define to which site the node should be allocated. If a node is covered by more than one site, it is allocated to the site directly adjacent to it. The nodes that are not directly adjacent to a site are allocated to the site that covers the lesser demand of the two sites. Figure 16 illustrates which demand nodes are allocated to each site.

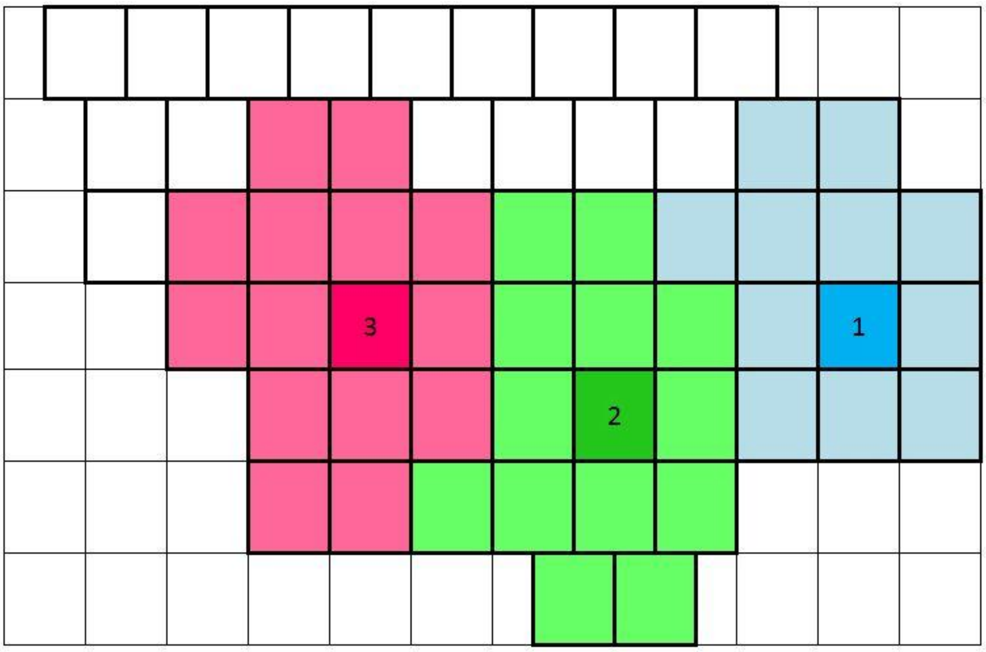

Figure 16 - The demand nodes allocated to each site

Parameters

The parameter N_j represents the number of households in each demand node. This is used to determine the number of households that each health post covers as well as the number of households allocated to each HCW. The resulting demand of each health post is indicated in the resource allocation model in Appendix F.

T_j is the average walking time from the health post to the demand node it is allocated to. As previously determined, it takes approximately 15 minutes to walk 1.25 kilometres. Based on this, the times listed in Table 7 were defined. The resulting walking times for the demand nodes are indicated in the resource allocation model in Appendix F.

Distance (D) from demand node to health post in km	Allocated average walking time in minutes
$D \leq 0.4$	5
$0.4 < D \leq 0.85$	10
$0.85 < D \leq 1.25$	15

Table 7 - The average walking time calculated on the basis of the distance

The parameter C is the allowable number of households that may be allocated to an HCW. This number is a constant value of 200 and is specified by the health post programme. The parameter K is equal to an HCW's daily working hours. An HCW works six hours or 360 minutes a day.

A_j is the time an HCW has left in the day after his or her walking time has been subtracted. In other words, if it takes 15 minutes to walk from the health post to the demand node, and vice versa, the worker has 360 – 2*15 = 330 minutes left to cover the households in the node.

4.2.2 Model results

The objective of the resource allocation model is to determine how many HCWs are needed at each health post. It also determines which households are allocated to each of the workers.

H_j determined how many households may be allocated to an HCW if he or she works in a certain demand node based on their time availability. This is evident in Table 8. For explanatory purposes, the demand nodes are grouped into Type I, II and III nodes.

Type of node	Average walking time in minutes to the node	# of households allocated to an HCW working in this node
I	5	194
II	10	188
III	15	183

Table 8 - Number of households allocated to an HCW on the basis of available time

The households were than manually allocated to the HCWs. Starting with Type I nodes, the HCWs were each allocated 194 households. When the remaining households in Type I nodes decreased to fewer than 194, Type II households were added, but then only 188 households were allocated to the HCW. When the remaining households in Type II nodes decreased to fewer than 188, the total remaining households both in Types II and III were added and divided by the number of Type III nodes. The number of households allocated to these workers may be fewer than 183, but considering that they walk much further than those in Type I and II nodes, this is permissible. The solution for each health post is discussed separately.

Health post 1: Vulcani Mawethu Secondary School

The demand nodes that are allocated to health post 1 are depicted in Figure 17. There are 2 060 households in total, and the model determined that 11 HCWs should be appointed at the health post. The relevant model is provided in Table F.1 in Appendix F.

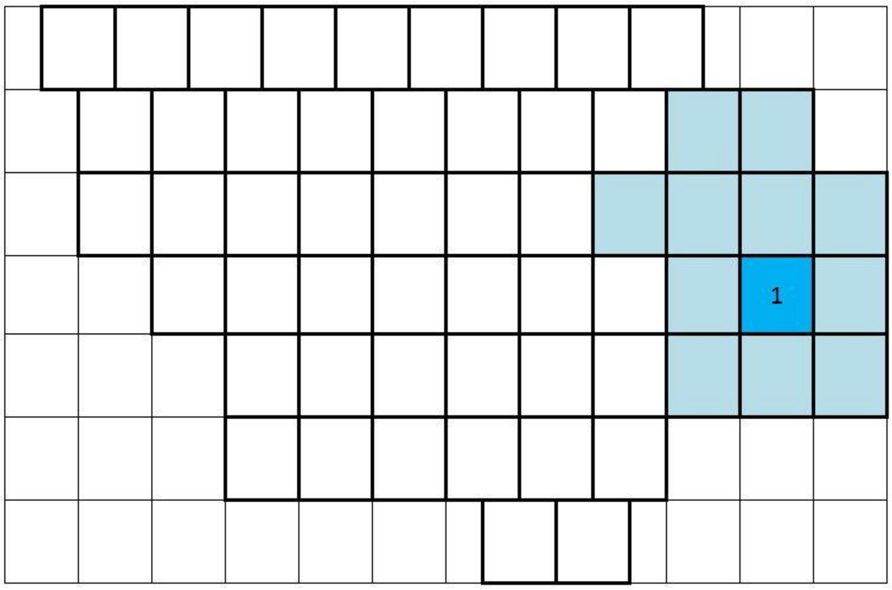

Figure 17 - The location of health post 1 and the demands covered by it

Allocating the households to the HCWs resulted in five workers receiving 194 households, four workers receiving 188 and the remaining two workers each receiving 169. A detailed list of the resource allocation is provided in Table G.1 in Appendix G.

Health post 2: Ezazi Primary School

The demand nodes that are allocated to health post 2 are indicated in Figure 18. There are 2 257 households in total and the model determined that 12 HCWs should be appointed at the health post. The relevant model is provided in Table F.2 in Appendix F.

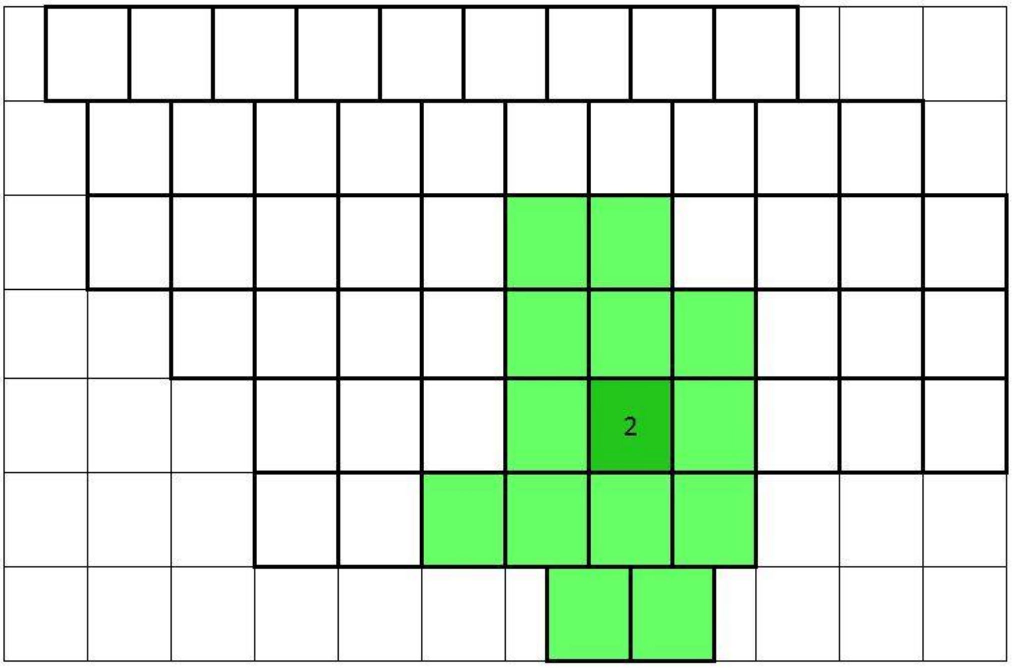

Figure 18 - The location of health post 2 and the demands covered by it

Allocating the households to the HCWs resulted in five workers receiving 194 households, five workers receiving 188, one worker receiving 174 and the last worker receiving 173. A detailed list of the resource allocation is provided in Table G.2 in Appendix G.

Health post 3: Bohlabatsatsi Primary School

The demand nodes that are allocated to health post 3 are indicated in Figure 19. There are 3 902 households in total and the model determined that 21 HCWs should be appointed at the health post. The relevant model is provided in Table F.3 in Appendix F.

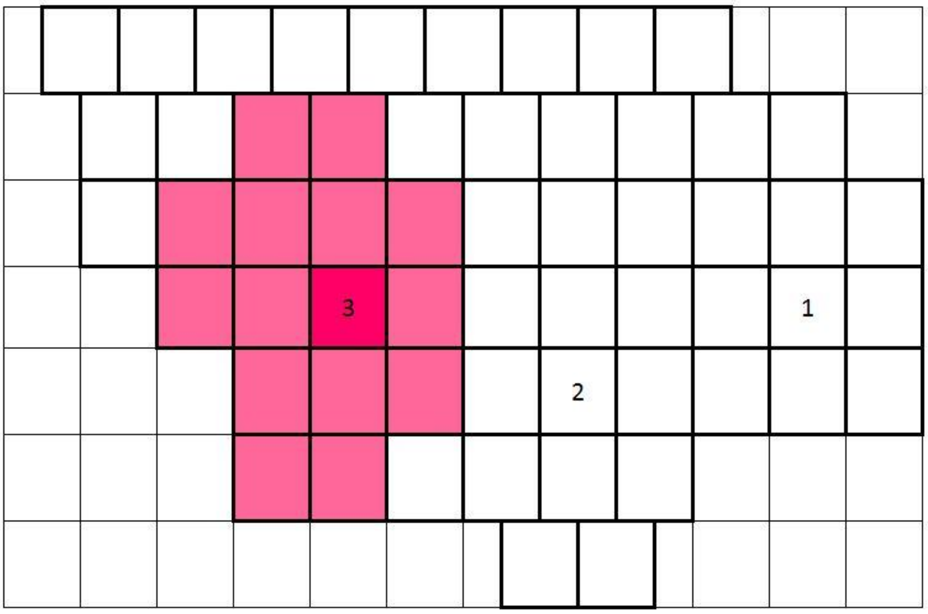

Figure 19 - The location of health post 3 and the demands covered by it

Allocating the households to the HCWs resulted in seven workers receiving 194 households, ten workers receiving 188 and the remaining four workers each receiving 166. A detailed list of the resource allocation is provided in Table G.3 in Appendix G.

4.3 Chapter summary

In this chapter it was determined that the NMS reduces the 27 possible sites to five sites. The DCM further reduces the five sites to three sites, while maximising the demand that will be covered. After identifying the final three sites, the number of HCWs was determined and allocated to the households. The next chapter concludes the dissertation by addressing possible future work and making recommendations.

Chapter 5

Conclusions and recommendations

5.1 Recommendations and future work

This dissertation provided possible solutions to the implementation of COPC in a community. However, not all the required information was available and the models were therefore developed on the basis of estimated values. To improve the accuracy of the models and to ensure that they are utilised to their full potential, it is recommended that detailed studies be performed. With the South African 2011 National Census currently underway, more accurate demand values could be used to improve the performance of the models.

The weighted average method and GIS could also be considered to improve the concept of health post location and resource allocation for COPC. These methods could be used in conjunction with the proposed models to ensure that an optimal solution is determined.

This report focused on allocating three health posts in Mamelodi West. However, the results of the NSM model identified that five health posts would be required to cover all the residents in the community. Therefore as the COPC programme grows and more funding becomes available, the remaining two health posts should be located at the identified locations. This should be done in the order indicated in Table 6. Consequently, the resource allocation was only completed for the final three health posts. Once the two remaining health posts are located, the resource allocation model could be used to accurately allocate HCWs to them.

The models that were developed could be adapted to include the remaining area of Mamelodi to ensure a uniform distribution of health posts across the community. The models could also be used in similar communities across the country to improve the implementation of COPC.

5.2 Conclusions

The aim of this dissertation was to show how mathematical modelling can be used to locate health posts in a community and to allocate resources to them. This project presented possible solutions to the process of implementing COPC in a community.

The NSM was developed to determine how many health posts should be located in the community in order to cover all the residents. The model also indicated where these health posts should be located from a predetermined list of possible sites. The second model, the DCM, further reduced the number of sites by focusing on covering the households with the highest demand. From this model it could be determined which health post was capable of covering a specific household. The resource allocation model was used to determine how many HCWs should be appointed at each health post. On the basis of this, it was possible to determine which households should be allocated to a specific HCW.

Health is vital for all human beings and it is therefore the responsibility of the government to ensure that its citizens receive the best possible treatment. It is envisioned that with the implementation of COPC in South Africa, the availability and accessibility of health care will be improved. The models developed in this dissertation could help to establishing COPC as a part of South Africa's health care system.

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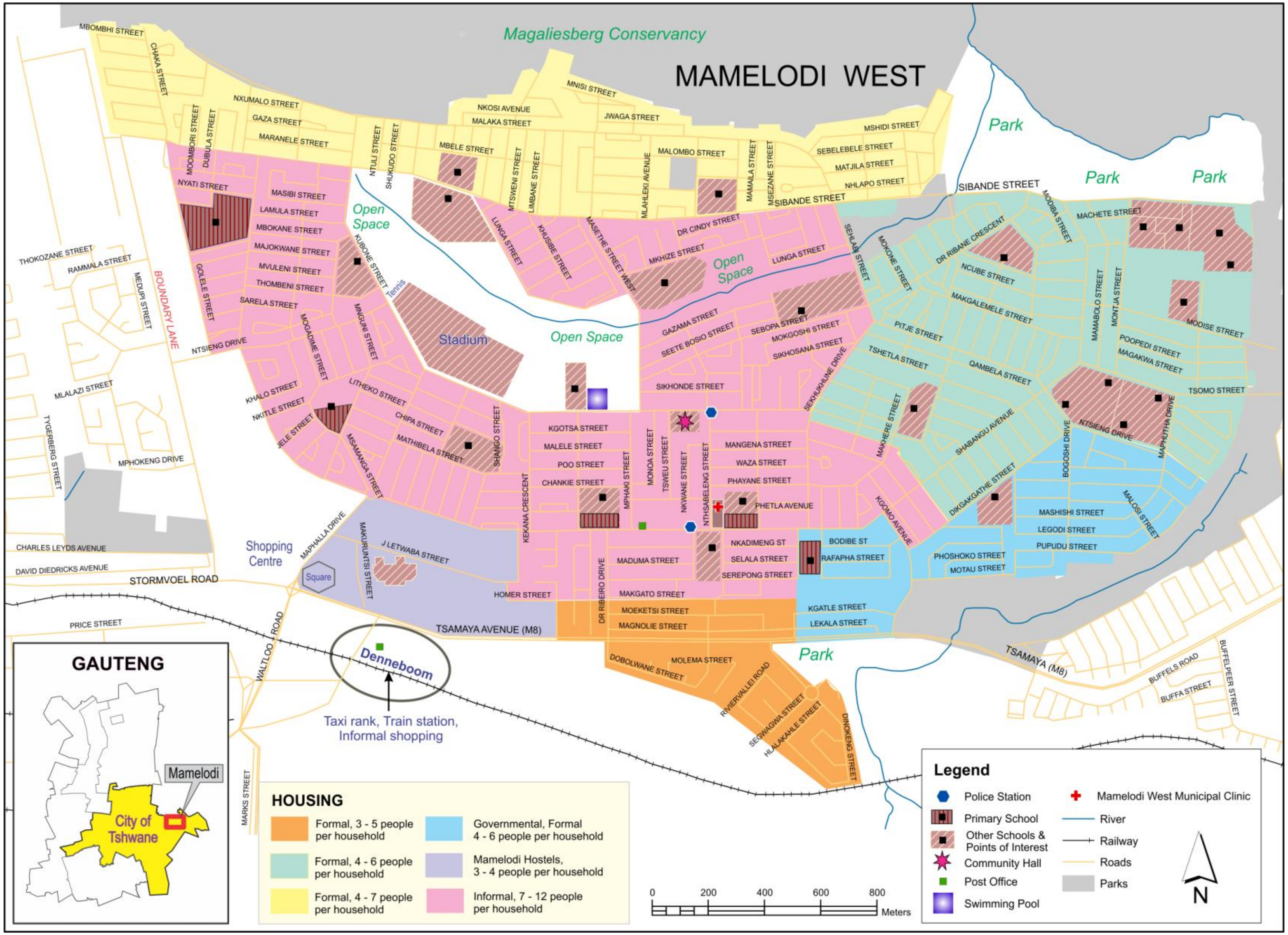
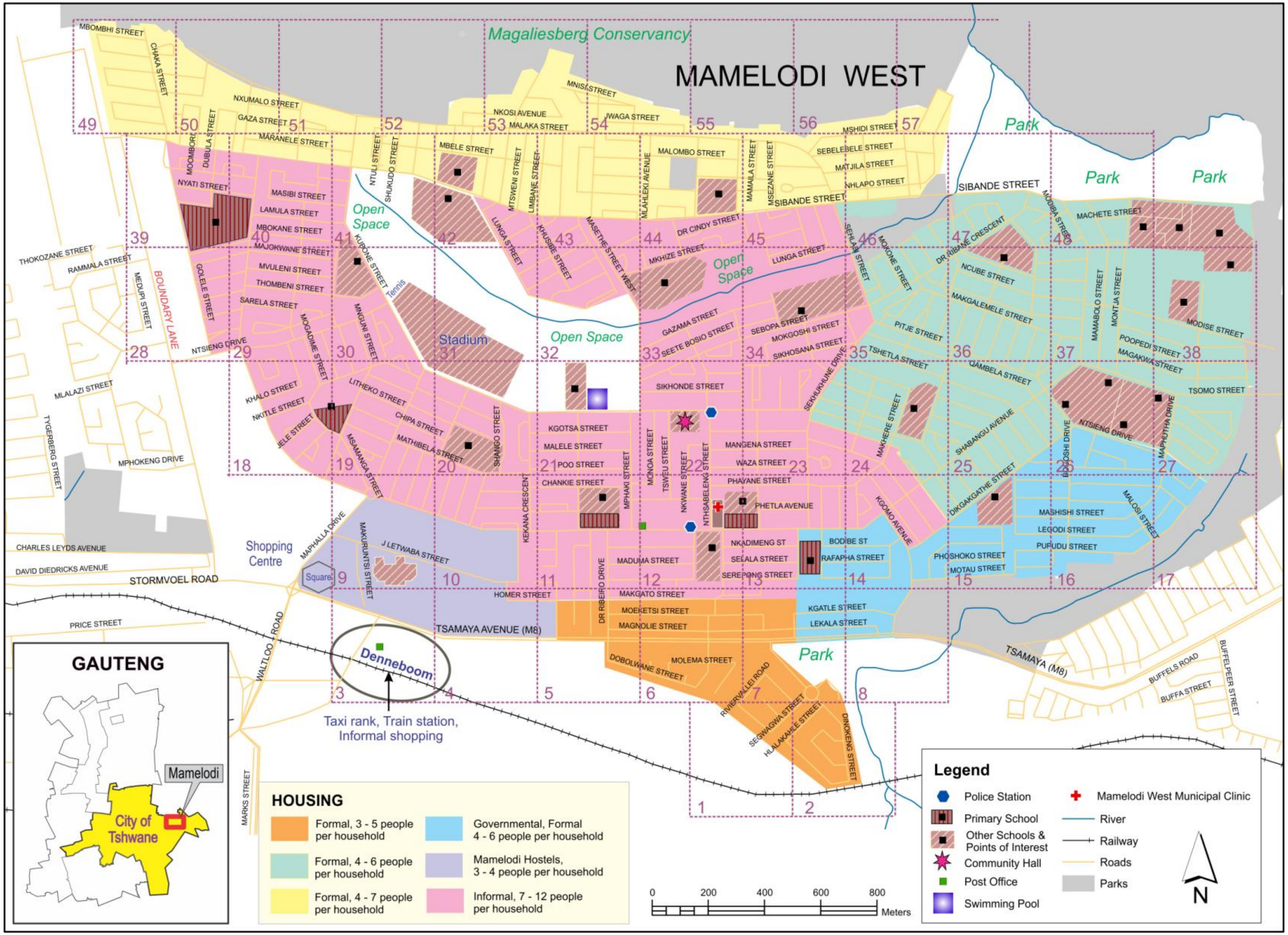
Appendix A - Detailed map of Mamelodi West




MAMELODI WEST
Magaliesberg Conservancy
Park
Open Space
Stadium
Shopping Centre
Square
Denneboom
Taxi rank, Train station, Informal shopping
BOUNDARY LANE
STORMVOEL ROAD
TSAMAYA AVENUE (M8)
CHARLES LEYDS AVENUE
DAVID DIEDRICKS AVENUE
SIBANDE STREET
GAUTENG
Mamelodi
City of Tshwane
HOUSING
Formal, 3 - 5 people per household
Governmental, Formal 4 - 6 people per household
Formal, 4 - 6 people per household
Mamelodi Hostels, 3 - 4 people per household
Formal, 4 - 7 people per household
Informal, 7 - 12 people per household
Legend
Police Station
Mamelodi West Municipal Clinic
Primary School
River
Other Schools & Points of Interest
Railway
Community Hall
Roads
Post Office
Parks
Swimming Pool
0
200
400
600
800
Meters
N

Appendix B

Number of sites model (NMS): Data

#	Name	Type	Address	Tel number
1	Mi Msezane Middle School	Primary	19693 Section W	(012) 805 4204
2	Vlakfontein Secondary School	High	Manya Str	(012) 805 2761
3	Mamelodi Sec K School	High	415 Lekganyane Str	(012) 805 1036
4	Refentse Primary School	Primary	9998 Block 10, Mantja Str	(012) 805 4297
5	Mmangolwane Primary School	Primary	19693 Section N	(012) 805 4623
6	Vulcani Mawethu Secondary School	High	9994 Section O	(012) 805 2627
7	Mamelodi Secondary School	High	9994 Section O, Tsomo	(012) 805 8834
8	Doctor IM Monare Primary School	Primary	994 Ntsieng Str	(012) 805 8667
9	Moretele Primary School	Primary	Section P, 5458	(012) 805 1288
10	Pheladi-nakene Primary School	Primary	Mofokeng Section Q	(012) 805 4154
11	Gamelodi Primary School	Primary	4500 Dr Ribane Str	(012) 805 8618
12	J Kekana Secondary School	High	6697 Block R	(012) 805 1690
13	Ndima Primary School	Primary	2967 Sec J Sibande Str	(012) 805 7473
14	Madiri Technical School	High	19691 Section N	(012) 805 4751
15	Morakoma Primary School	Primary	19178 Kubone Str	(012) 805 0079
16	FF Ribiero Primary School	Primary	283 Shabangu Str	(012) 805 4180
17	Ezazi Primary School	Primary	6884 Section S	(012) 805 0426
18	Agnes Chidi Primary School	Primary	7402 Jjale Str, Block V	(012) 805 4530
19	Tshimollo Primary School	Primary	1693 Section E	(012) 805 4114
20	Bohlabatsatsi Primary School	Primary	563 Makhusela Str	(012) 805 1054
21	Umthomba Primary School	Primary	116 Sec C Msimang Str	(012) 805 1613
22	Emthunzini Primary School	Primary	1485 Section D	(012) 805 4637
23	Jafta Mahlangu Secondary School	Primary	19179 Section D	(012) 805 3615
24	Zamintuthuko Primary School	Primary	2329 Section G	(012) 805 4270
25	Shirinda Primary School	Primary	1693 Section G	(012) 805 4114
26	Community Hall	Hall	Cnr Dr Kubone and Tsweu Str	-
27	Mamelodi West Clinic	Clinic	Cnr Tshabangu and Ntshabeleng Str	(012) 358 6433/6432/ 6431

Table B.1 - Additional information on the 27 possible health post locations

Site number	X co-ordinate	Y co-ordinate

1	11.25	5.14
2	11.62	5.12
3	11.74	4.84
4	10.9	5.17
5	11.34	4.5
6	10.59	3.73
7	11.1	3.64
8	10.2	3.5
9	9.45	2.17
10	8.67	3.53
11	9.56	4.93
12	7.59	4.36
13	6.7	5.45
14	6.2	4.65
15	5.45	3.78
16	5.63	2.7
17	7	2.7
18	2.65	7.25
19	6.62	6.2
20	4.3	3.25
21	2.92	3.59
22	3.22	4.84
23	4.17	5.67
24	4.2	5.67
25	1.73	5.23
26	6.42	3.39
27	6.73	2.62

Table B.2 - The x-y co-ordinates of the 27 possible health post locations

Site number	X co-ordinate	Y co-ordinate
1	7	0.5
2	8	0.5
3	3.5	1.5
4	4.5	1.5
5	5.5	1.5
6	6.5	1.5
7	7.5	1.5
8	8.5	1.5
9	3.5	2.5
10	4.5	2.5
11	5.5	2.5
12	6.5	2.5
13	7.5	2.5
14	8.5	2.5
15	9.5	2.5
16	10.5	2.5
17	11.5	2.5
18	2.5	3.5
19	3.5	3.5
20	4.5	3.5
21	5.5	3.5
22	6.5	3.5
23	7.5	3.5

24	8.5	3.5
25	9.5	3.5
26	10.5	3.5
27	11.5	3.5
28	1.5	4.5
29	2.5	4.5
30	3.5	4.5
31	4.5	4.5
32	5.5	4.5
33	6.5	4.5
34	7.5	4.5
35	8.5	4.5
36	9.5	4.5
37	10.5	4.5
38	11.5	4.5
39	1.5	5.5
40	2.5	5.5
41	3.5	5.5
42	4.5	5.5
43	5.5	5.5
44	6.5	5.5
45	7.5	5.5
46	8.5	5.5
47	9.5	5.5
48	10.5	5.5
49	1	6.5
50	2	6.5
51	3	6.5
52	4	6.5
53	5	6.5
54	6	6.5
55	7	6.5
56	8	6.5
57	9	6.5

Table B.3 - The x-y co-ordinates of the 57 demand nodes

Appendix C

Demand covered model (DCM): Data

#	Previous #	Name	Type	Address	Tel number
1	6	Vulcani Mawethu Secondary School	High	9994 Section O	(012) 805 2627
2	17	Ezazi Primary School	Primary	6884 Section S	(012) 805 0426
3	19	Tshimollo Primary School	Primary	1693 Section E	(012) 805 4114
4	20	Bohlabatsatsi Primary School	Primary	563 Makhusela	(012) 805 1054
5	25	Shirinda Primary School	Primary	1693 Section G	(012) 805 4114

Table C.1 - The resulting five possible health post locations defined by the NSM

Demand node	**The number of houses per type of housing**						**Number of houses per node**	**Number of residents per node**
	A	B	C	D	E	F		
1	53	-	-	-	-	-	53	213
2	16	-	-	-	-	-	16	488
3	-	200	-	-	-	-	200	1000
4	-	700	28	-	-	-	728	3787
5	70	-	77	-	-	-	147	1011
6	150	-	69	-	-	-	219	1261
7	47	-	15	42	-	-	104	534
8	-	-	-	36	-	-	36	185
9	-	400	49	-	-	-	449	2450
10	-	700	156	-	-	-	856	5005
11	-	-	263	-	-	-	263	2467
12	-	-	166	-	-	-	166	1605
13	-	-	190	44	-	-	234	2060
14	-	-	125	144	18	-	287	1992
15	-	-	-	205	43	-	248	1229
16	-	-	-	223	-	-	223	1115
17	-	-	-	66	-	-	66	321
18	-	-	186	-	-	-	186	1779

19	-	-	230	-	-	-	230	2212
20	-	-	110	-	-	-	110	1025
21	-	-	160	-	-	-	160	1513
22	-	-	219	-	-	-	219	2099
23	-	-	232	-	33	-	232	2353
24	-	-	30	-	148	-	178	1039
25	-	-	-	8	236	-	244	1236
26	-	-	-	70	26	-	96	480
27	-	-	-	240	-	-	240	1217
28	-	-	94	-	-	-	94	887
29	-	-	218	-	-	-	218	2077
30	-	-	86	-	-	-	86	807
31	-	-	32	-	-	-	32	317
32	-	-	122	-	-	-	122	1194
33	-	-	102	-	-	-	102	978
34	-	-	120	-	-	-	120	1137
35	-	-	2	-	212	-	214	1075
36	-	-	-	-	270	-	270	1337
37	-	-	-	-	252	-	252	1285
38	-	-	-	-	86	-	86	423
39	-	-	84	-	-	24	108	931
40	-	-	184	-	-	48	232	2022
41	-	-	-	-	-	80	80	446
42	-	-	46	-	-	136	182	1171
43	-	-	38	-	-	209	247	1500
44	-	-	50	-	-	122	172	1133
45	-	-	92	-	-	142	234	1646
46	-	-	-	-	24	120	142	774
47	-	-	-	-	46	-	46	231
48	-	-	-	-	75	-	75	370
49	-	-	-	-	-	180	180	994
50	-	-	-	-	-	106	106	570
51	-	-	-	-	-	56	56	315
52	-	-	-	-	-	46	46	240
53	-	-	-	-	-	76	76	422
54	-	-	-	-	-	68	68	360

55	-	-	-	-	-	18	18	90
56	-	-	-	-	-	20	20	102
57		-	-	-	-	40	40	220
Total demand for Mamelodi West							10659	66734

Table C.2 - The demand of each demand node based on the type of housing

Appendix D

Number of sites model (NMS): LINGO model

```
Model:
!The model must provide a generic approach to determine the minimum number of health posts
that should be located in the community in order to cover all the residents;

Title Min Number of Sites Model (NSM);

Sets:
sites/1..27/: s, a, b;
nodes/1..57/: c, d;
distance(sites, nodes): h;
post(sites, nodes): p;
Endsets

Data:
c  =    7      8      3.5    4.5     5.5    6.5    7.5    8.5    3.5    4.5    5.5   6.5
        7.5    8.5    9.5    10.5    11.5   2.5    3.5    4.5    5.5    6.5    7.5   8.5
        9.5    10.5   11.5    1.5    2.5    3.5    4.5    5.5    6.6    7.5    8.5   9.5
        10.5   11.5    1.5    2.5    3.5    4.5    5.5    6.5    7.5    8.5    9.5
        10.5    1      2      3      4      5      6      7             8      9;
d  =    0.5    0.5    1.5    1.5    1.5    1.5    1.5    1.5    2.5    2.5    2.5    2.5
        2.5    2.5    2.5    2.5    2.5    3.5    3.5    3.5    3.5    3.5    3.5    3.5
        3.5    3.5    3.5    4.5    4.5    4.5    4.5    4.5    4.5    4.5    4.5    4.5
        4.5    4.5    5.5    5.5    5.5    5.5    5.5    5.5    5.5    5.5    5.5    5.5
        6.5    6.5    6.5    6.5    6.5    6.5    6.5    6.5    6.5;
a  =    11.25    11.62    11.74    10.9    11.34    10.59    11.1    10.2    9.45
        8.67     9.56     7.59     6.7     6.2       5.45    5.62    7       2.65
        6.62     4.3      2.92     3.22    4.17      4.2     1.73    6.42    6.73;
b  =    5.14     5.12     4.84     5.17    4.5       3.73    3.64    3.5     2.17
        3.53     4.93     4.36     5.45    4.65      3.78    2.7     2.7     7.25
        6.2    3.25     3.59     4.84    5.67      5.67    5.23    3.39    2.62
distance   =   1 1, 1 2, 1 3, 1 4, 1 5, 1 6, 1 7, 1 8, 1 9, 1 10, 1 11, 1 12,
        1 13, 1 14, 1 15, 1 16, 1 17, 1 18, 1 19, 1 20, 1 21, 1 22, 1 23,
        1 24, 1 25, 1 26, 1 27, 1 28, 1 29, 1 30, 1 31, 1 32, 1 33, 1 34,
        1 35, 1 36, 1 37, 1 38, 1 39, 1 40, 1 41, 1 42, 1 43, 1 44, 1 45,
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        2 57
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        3 24, 3 25, 3 26, 3 27, 3 28, 3 29, 3 30, 3 31, 3 32, 3 33, 3 34,
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    23 11, 23 12, 23 13, 23 14, 23 15, 23 16, 23 17, 23 18, 23 19, 23 20,
    23 21, 23 22, 23 23, 23 24, 23 25, 23 26, 23 27, 23 28, 23 29, 23 30,
    23 31, 23 32, 23 33, 23 34, 23 35, 23 36, 23 37, 23 38, 23 39, 23 40,
    23 41, 23 42, 23 43, 23 44, 23 45, 23 46, 23 47, 23 48, 23 49, 23 50,
    23 51, 23 52, 23 53, 23 54, 23 55, 23 56, 23 57
        24 1, 24 2, 24 3, 24 4, 24 5, 24 6, 24 7, 24 8, 24 9, 24 10,
    24 11, 24 12, 24 13, 24 14, 24 15, 24 16, 24 17, 24 18, 24 19, 24 20,
    24 21, 24 22, 24 23, 24 24, 24 25, 24 26, 24 27, 24 28, 24 29, 24 30,
    24 31, 24 32, 24 33, 24 34, 24 35, 24 36, 24 37, 24 38, 24 39, 24 40,
    24 41, 24 42, 24 43, 24 44, 24 45, 24 46, 24 47, 24 48, 24 49, 24 50,
    24 51, 24 52, 24 53, 24 54, 24 55, 24 56, 24 57
        25 1, 25 2, 25 3, 25 4, 25 5, 25 6, 25 7, 25 8, 25 9, 25 10,
    25 11, 25 12, 25 13, 25 14, 25 15, 25 16, 25 17, 25 18, 25 19, 25 20,
    25 21, 25 22, 25 23, 25 24, 25 25, 25 26, 25 27, 25 28, 25 29, 25 30,
    25 31, 25 32, 25 33, 25 34, 25 35, 25 36, 25 37, 25 38, 25 39, 25 40,
    25 41, 25 42, 25 43, 25 44, 25 45, 25 46, 25 47, 25 48, 25 49, 25 50,
    25 51, 25 52, 25 53, 25 54, 25 55, 25 56, 25 57
        26 1, 26 2, 26 3, 26 4, 26 5, 26 6, 26 7, 26 8, 26 9, 26 10,
    26 11, 26 12, 26 13, 26 14, 26 15, 26 16, 26 17, 26 18, 26 19, 26 20,
    26 21, 26 22, 26 23, 26 24, 26 25, 26 26, 26 27, 26 28, 26 29, 26 30,
    26 31, 26 32, 26 33, 26 34, 26 35, 26 36, 26 37, 26 38, 26 39, 26 40,
    26 41, 26 42, 26 43, 26 44, 26 45, 26 46, 26 47, 26 48, 26 49, 26 50,
    26 51, 26 52, 26 53, 26 54, 26 55, 26 56, 26 57
        27 1, 27 2, 27 3, 27 4, 27 5, 27 6, 27 7, 27 8, 27 9, 27 10,
    27 11, 27 12, 27 13, 27 14, 27 15, 27 16, 27 17, 27 18, 27 19, 27 20,
    27 21, 27 22, 27 23, 27 24, 27 25, 27 26, 27 27, 27 28, 27 29, 27 30,
    27 31, 27 32, 27 33, 27 34, 27 35, 27 36, 27 37, 27 38, 27 39, 27 40,
    27 41, 27 42, 27 43, 27 44, 27 45, 27 46, 27 47, 27 48, 27 49, 27 50,
    27 51, 27 52, 27 53, 27 54, 27 55, 27 56, 27 57;
Enddata

[Objective]     Min = @sum(sites(i): s(i));

@for(distance(i,j): h(i,j) = @abs(c(j) - a(i)) + @abs(d(j) - b(i)));

@for(post(i,j): @for(distance(i,j): p(i,j) = @if(h(i,j) #LE# 3.2, 1, 0)));

@for(nodes(j): @sum(post(i,j): p(i,j)*s(i)) >= 1);

@for(Sites(i): @bin(s(i)));

End
```

Appendix E

Demand covered model (DCM): LINGO model

```
Model:
!The model must provide a generic approach to maximise the demand covered if fewer sites are located than required;

Title Demand Covered Model (DCM);

Sets:
sites/1..5/: s, a, b;
nodes/1..57/: n, g, c, d;
distance(sites, nodes): h;
post(sites, nodes): p;
Endsets

Data:
c  =   7      8      3.5    4.5    5.5    6.5    7.5    8.5    3.5    4.5    5.5    6.5
       7.5    8.5    9.5    10.5   11.5   2.5    3.5    4.5    5.5    6.5    7.5    8.5
       9.5    10.5   11.5   1.5    2.5    3.5    4.5    5.5    6.6    7.5    8.5    9.5
       10.5   11.5    1.5   2.5    3.5    4.5    5.5    6.5    7.5    8.5    9.5
       10.5    1      2      3      4      5      6      7      8      9;
d  =   0.5    0.5    1.5    1.5    1.5    1.5    1.5    1.5    2.5    2.5    2.5    2.5
       2.5    2.5    2.5    2.5     2.5   3.5    3.5    3.5    3.5    3.5    3.5    3.5
       3.5    3.5    3.5    4.5    4.5    4.5    4.5    4.5    4.5    4.5    4.5    4.5
       4.5    4.5    5.5    5.5    5.5    5.5    5.5    5.5    5.5    5.5    5.5    5.5
       6.5    6.5    6.5    6.5    6.5    6.5    6.5    6.5    6.5;
a  =   10.59    7      6.62    4.3     1.73;
b  =    3.73     2.7    6.2     3.25    5.23;
g  =   213    488    1000   3787   1011   1261   534    185    2450   5005   2467
       1605   2060   1992   1229   1115   321    1779   2212   1025   1513   2099
       2353   1039   1236    480   1217   887    2077   807    317    1194   978
       1137   1075   1337   1285   423    931    2020   446    1171   1500   1133
       1646   774   231   370   994   570   315   246   422   360   90   102   220;
distance  =   1 1, 1 2, 1 3, 1 4, 1 5, 1 6, 1 7, 1 8, 1 9, 1 10, 1 11, 1 12,
       1 13, 1 14, 1 15, 1 16, 1 17, 1 18, 1 19, 1 20, 1 21, 1 22, 1 23,
       1 24, 1 25, 1 26, 1 27, 1 28, 1 29, 1 30, 1 31, 1 32, 1 33, 1 34,
       1 35, 1 36, 1 37, 1 38, 1 39, 1 40, 1 41, 1 42, 1 43, 1 44, 1 45,
       1 46, 1 47, 1 48, 1 49, 1 50, 1 51, 1 52, 1 53, 1 54, 1 55, 1 56,
       1 57
             2 1, 2 2, 2 3, 2 4, 2 5, 2 6, 2 7, 2 8, 2 9, 2 10, 2 11, 2 12,
       2 13, 2 14, 2 15, 2 16, 2 17, 2 18, 2 19, 2 20, 2 21, 2 22, 2 23,
       2 24, 2 25, 2 26, 2 27, 2 28, 2 29, 2 30, 2 31, 2 32, 2 33, 2 34,
       2 35, 2 36, 2 37, 2 38, 2 39, 2 40, 2 41, 2 42, 2 43, 2 44, 2 45,
       2 46, 2 47, 2 48, 2 49, 2 50, 2 51, 2 52, 2 53, 2 54, 2 55, 2 56,
       2 57
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           3 1, 3 2, 3 3, 3 4, 3 5, 3 6, 3 7, 3 8, 3 9, 3 10, 3 11, 3 12,
      3 13, 3 14, 3 15, 3 16, 3 17, 3 18, 3 19, 3 20, 3 21, 3 22, 3 23,
      3 24, 3 25, 3 26, 3 27, 3 28, 3 29, 3 30, 3 31, 3 32, 3 33, 3 34,
      3 35, 3 36, 3 37, 3 38, 3 39, 3 40, 3 41, 3 42, 3 43, 3 44, 3 45,
      3 46, 3 47, 3 48, 3 49, 3 50, 3 51, 3 52, 3 53, 3 54, 3 55, 3 56,
      3 57
           4 1, 4 2, 4 3, 4 4, 4 5, 4 6, 4 7, 4 8, 4 9, 4 10, 4 11, 4 12,
      4 13, 4 14, 4 15, 4 16, 4 17, 4 18, 4 19, 4 20, 4 21, 4 22, 4 23,
      4 24, 4 25, 4 26, 4 27, 4 28, 4 29, 4 30, 4 31, 4 32, 4 33, 4 34,
      4 35, 4 36, 4 37, 4 38, 4 39, 4 40, 4 41, 4 42, 4 43, 4 44, 4 45,
      4 46, 4 47, 4 48, 4 49, 4 50, 4 51, 4 52, 4 53, 4 54, 4 55, 4 56,
      4 57
           5 1, 5 2, 5 3, 5 4, 5 5, 5 6, 5 7, 5 8, 5 9, 5 10, 5 11, 5 12,
      5 13, 5 14, 5 15, 5 16, 5 17, 5 18, 5 19, 5 20, 5 21, 5 22, 5 23,
      5 24, 5 25, 5 26, 5 27, 5 28, 5 29, 5 30, 5 31, 5 32, 5 33, 5 34,
      5 35, 5 36, 5 37, 5 38, 5 39, 5 40, 5 41, 5 42, 5 43, 5 44, 5 45,
      5 46, 5 47, 5 48, 5 49, 5 50, 5 51, 5 52, 5 53, 5 54, 5 55, 5 56,
      5 57;
Enddata

[Objective]      Max = @sum(nodes(j): g(j)*n(j));

@for(distance(i,j): h(i,j) = @abs(c(j) - a(i)) + @abs(d(j) - b(i)));

@for(post(i,j): @for(distance(i,j): p(i,j) = @if(h(i,j) #LE# 3.2, 1, 0)));

@for(nodes(j): n(j) - @sum(post(i,j): p(i,j)*s(i)) <= 0);

@sum(sites(i): s(i)) = 3;

@for(Sites(i): @bin(s(i)));

@for(nodes(j): @bin(n(j)));

End
```

Appendix F

Resource allocation model: Excel model

Demand node	# of Households per node (Nj)	Walking time from health post to node (Tj)	Available time left for visiting (Aj)	# of Households per HCW (Hj)	# of HCWs per node (Wj)
1	248	10	340	188	1.32
2	223	5	350	194	1.15
3	66	10	340	188	0.35
4	244	5	350	194	1.26
5	96	5	350	194	0.49
6	240	5	350	194	1.24
7	214	15	330	183	1.17
8	270	10	340	188	1.44
9	252	5	350	194	1.30
10	86	10	340	188	0.46
11	46	15	330	183	0.25
12	75	10	340	188	0.40
The number of HCWs to allocate to the health post:					11

Table F.1 - The resource allocation model for health post 1

Demand node	# of Households per node (N_j)	Walking time from health post to node (T_j)	Available time left for visiting (A_j)	# of Households per HCW (H_j)	# of HCWs per node (W_j)
1	53	15	330	183	0.29
2	126	10	340	188	0.67
3	147	15	330	183	0.80
4	219	10	340	188	1.16
5	104	5	350	194	0.54
6	36	10	340	188	0.19
7	166	5	350	194	0.86
8	234	5	350	194	1.21

9	287	5	350	194	1.48
10	219	10	340	188	1.16
11	366	5	350	194	1.37
12	178	10	340	188	0.95
13	102	15	330	183	0.56
14	120	10	340	188	0.64
Number of HCWs to allocate to the health post:					12

Table F.2 - The resource allocation model for health post 2

Demand node	# of Households per node (N_j)	Walking time from health post to node (T_j)	Available time left for visiting (A_j)	# of Households per HCW (H_j)	# of HCWs per node (W_j)
1	200	15	330	183	1.09
2	728	10	340	188	3.87
3	449	10	340	188	2.39
4	856	5	350	194	4.41
5	263	10	340	188	1.40
6	186	10	340	188	0.99
7	230	5	350	194	1.19
8	110	5	350	194	0.57
9	160	5	350	194	0.82
10	218	15	330	183	1.19
11	86	10	340	188	0.46
12	32	5	350	194	0.16
13	122	10	340	188	0.65
14	80	15	330	183	0.44
15	182	10	340	188	0.97
The number of HCWs to allocate to the health post:					21

Table F.3 - The resource allocation model for health post 3

Appendix G

Resource allocation model: Solutions

HCW	Demand node												**# of households**
	1	2	3	4	5	6	7	8	9	10	11	12	
1	-	194	-	-	-	-	-	-	-	-	-	-	194
2	-	29	-	69	96	-	-	-	-	-	-	-	194
3	-	-	-	175	-	-	-	-	19	-	-	-	194
4	-	-	-	-	-	-	-	-	194	-	-	-	194
5	-	-	-	-	-	155	-	-	39	-	-	-	194
6	37	-	66	-	-	85	-	-	-	-	-	-	188
7	188	-	-	-	-	-	-	-	-	-	-	-	188
8	23	-	-	-	-	-	-	165	-	-	-	-	188
9	-	-	-	-	-	-	-	105	-	83	-	-	188
10	-	-	-	-	-	-	45	-	-	3	46	75	169
11	-	-	-	-	-	-	169	-	-	-	-	-	169
Total:	248	223	66	244	96	240	214	270	252	86	46	75	2060

Table G.1 - The allocation of households to the HCWs of health post 1

HCW	Demand node														# of households
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	-	-	-	104	-	-	-	90	-	-	-	-	-	-	194
2		-	-	-	-	-	50	144	-	-	-	-	-	-	194
3	-	-	-	-	-	-	116	-	-	-	78	-	-	-	194
4	-	-	-	-	-	-	-	-	6	-	188	-	-	-	194
5	-	-	-	-	-	-	-	-	194	-	-	-	-	-	194
6	-	65	-	-	-	36	-	-	87	-	-	-	-	-	188
7	-	61	-	127	-	-	-	-	-	-	-	-	-	-	188
8	-	-	-	92	-	-	-	-	-	96	-	-	-	-	188
9	-	-	-	-	-	-	-	-	-	123	-	65	-	-	188
10	-	-	-	-	-	-	-	-	-	-	-	113	-	75	188
11	53	-	121	-	-	-	-	-	-	-	-	-	-	-	174
12	-	-	26	-	-	-	-	-	-	-	-	-	102	45	173
Total:	53	126	147	219	104	36	166	234	287	219	266	178	102	120	2257

Table G.2 - The allocation of households to the HCWs of health post 2

HCW	Demand node															# of households
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	-	-	-	194	-	-	-	-	-	-	-	-	-	-	-	194
2	-	-	-	194	-	-	-	-	-	-	-	-	-	-	-	194
3	-	-	-	194	-	-	-	-	-	-	-	-	-	-	-	194
4	-	-	-	194	-	-	-	-	-	-	-	-	-	-	-	194
5	-	-	-	80	-	-	114	-	-	-	-	-	-	-	-	194
6	-	-	-	-	-	-	116	78	-	-	-	-	-	-	-	194
7	-	-	-	-	-	-	-	32	160	-	-	2	-	-	-	194
8	-	-	-	-	-	-	-	-	-	-	36	30	122	-	-	188
9	-	-	-	-	-	-	-	-	-	-	50	-	-	-	138	188
10	-	-	-	-	188	-	-	-	-	-	-	-	-	-	-	188
11	-	113	-	-	75	-	-	-	-	-	-	-	-	-	-	188
12	-	188	-	-	-	-	-	-	-	-	-	-	-	-	-	188
13	-	188	-	-	-	-	-	-	-	-	-	-	-	-	-	188
14	-	188	-	-	-	-	-	-	-	-	-	-	-	-	-	188
15	-	51	137	-	-	-	-	-	-	-	-	-	-	-	-	188
16	-	188	-	-	-	-	-	-	-	-	-	-	-	-	-	188
17	-	-	124	-	64	-	-	-	-	-	-	-	-	-	-	188
18	-	-	-	-	-	-	122	-	-	-	-	-	-	-	44	166
19	166	-	-	-	-	-	-	-	-	-	-	-	-	-	-	166
20	34	-	-	-	-	-	-	-	-	132	-	-	-	-	-	166
21	-	-	-	-	-	-	-	-	-	36	-	-	-	80	-	166
Total:	200	728	449	856	263	186	230	110	160	218	86	32	122	80	182	3902

Table G.3 - The allocation of households to the HCWs of health post 3