The Davao City Health System:  
An Approach to Optimally Locating Community Health Facilities

Ma. Esmeralda Silva  
*Center for Economic Development, Carnegie Mellon University, Pittsburgh, PA, USA 15213*  
(Email: myra.silva@gmail.com)

Michael P. Johnson  
*Associate Professor of Management Science and Urban Affairs, H. John Heinz School of Public Policy and Management, Carnegie Mellon University, Pittsburgh, PA, USA 15213*  
(Email: johnson2@andrew.cmu.edu)

**Abstract.** Two hierarchical location-allocation models are used to locate two types of community-based health facilities in Davao City, Philippines. Oftentimes, locating health facilities are motivated by factors such as politics and resource availability. Different optimization approaches to locating a mix of these health facilities across the rural and urban areas of the city. Computations results are evaluated based on three performance metrics: operating costs, average weighted travel distance and population coverage.

1 INTRODUCTION

Developing countries face the problem of improving their health care delivery systems but lack the necessary resources to do this (Oppong and Hodgson, 1994). For countries like the Philippines, local governments are faced with the dilemma of prioritizing conflicting yet equally important issues. With limited financial and human resources, local governments must decide which local initiatives to implement first. These local initiatives touch on economic development, peace and order and social development, which, for poorer municipalities, cities and provinces, are badly needed by the local population. Often times, social development initiatives, including health care, are de-prioritized. It is a misnomer that, in order to have an effective, efficient and equitable local health care system, a substantial investment must be made. In this study, I will show that substantial improvements, in terms of cost savings as well as population coverage, could be made at current investment levels on the part of the local government.

For developing countries, the accessibility of these facilities plays a crucial role in a client/patient’s decision of whether to go to a clinic or hospital to receive care. Once decided, the facility’s location and the factors it takes to reach it (i.e. travel time, travel cost) influence the choice of facilities available to the patient. The choices available becomes fewer as one goes to more rural areas. Oftentimes, these areas are poor, sparsely populated and far from the urban centers. For a patient living in these areas, his/her access to a health facility is severely constrained by the time and costs associated with a visit. There are cases where patients postpone their visit to the hospital until
it is too late – when they are already very sick and need medical attention.

This study will show how the accessibility of health facilities can be enhanced through the application of 2 different optimization models – the Hierarchical Coverage Model (HCM) and the Hierarchical Median Model (HMM). Computational results provide important insights into the problem and offer significant policy implications.

1.1 RELATED LITERATURE

1.1.1 Accessibility of health services

The accessibility of health facilities by the target population plays an important role in ensuring that health services within these facilities are efficiently and effectively delivered. Physical accessibility of health services is determined by the geographical location of client homesteads in relation to available facilities, by physical and topographical barriers and by the modes of transport that are available to reach these destinations (Tanser, et al, 2001). Over the years, numerous studies have shown that geographical accessibility of health services strongly influences the utilization of these services. Limited physical access to primary health care is a major factor contributing to the poor health of populations in developing countries (Tanser, 2002). By making health facilities more accessible, people are more likely to utilize the services offered in these facilities.

More accessible health facilities translate to a more equitable access to health services. In health, equity manifests itself in the distribution, access to and utilization of health services between population groups (Thaddeus and Maine, 1994). It is an important factor in improving the health status of marginalized population groups, including the poor, elderly, women and children. Implementing agencies must make special investments to reach these populations. The identification of health inequity entails normative judgment premised upon (a) one’s theories of justice; (b) one’s theories of society; and (c) one’s reasoning underlying the genesis of health inequalities (Kawachi, et al, 2002). On the other hand, equity is also hard to measure. There are not many performance measures that fully capture “equity”. For example, in measuring equitable access to health care, access is a complex inter-linkage of both physical and human factors in addition to mere proximity to target locations (Tanser, 2002).

1.1.2 Spatial Accessibility

Spatial accessibility is defined as the fusion of 2 barriers to “realized access” or utilization that are spatial in nature: availability and accessibility. Availability refers to the number of local service points from which a client can choose while accessibility is the travel impedance (distance or
time) between patient location and service points (Guagliardo, 2004). Consumers are required to travel over a distance to avail of a service. Given a specified geographic area, there are a number of facilities that are available. An individual must appraise his need or demand for a service and the number of trips he will make in light of both the value or attractiveness of the service facility at a given location and the costs involved in traveling to the facility (Morrill and Kelley, 1970). This interaction between the demand for a service and the availability of one or more facilities serves as the basis for spatial accessibility studies.

Geographical distance closely interrelates with 2 factors: travel time and transportation cost (Buor, 2002). Longer distances entail longer travel times as well as higher transportation costs. In a study on the effect of distance on maternal mortality, Thaddeus and Maine presented three different phases in the decision-making process where mothers delay utilizing maternal care (Figure 1). The accessibility of health facilities directly affects the first and second phase of delay. In phase 1, there are a number of factors that influence this delay but distance between patients and the nearest health facility presents the biggest obstacle to utilization. Longer distances are “actual obstacles to reaching a health facility” (Thaddeus and Maine, 1994). Combined with bad roads and the lack of transportation, these are a potent combination that a disincentive to even try to get care.

Phase 2 delays, on the other hand, are associated with the actual accessibility of health services. Factors that create Phase 2 delays include the location of health facilities, travel distance that results from this distribution and transportation means necessary to cover these distances (Thaddeus and Maine, 1994). In developing countries, studies amply show the important role of distance in reducing the use of health facilities, especially in rural areas (Buor, 2003). Generally, the urban populace has better access to health facilities compared to their rural counterparts. There is a greater incentive for local governments to invest in health facilities in urban areas since there is greater population concentration. This disparity becomes more acute when the issue shifts to travel distances and the means it takes to reach these facilities. Because of the relatively wider geographic

![Figure 1. Schematic Representation of the effect of various factors on the different phases of delay](image-url)
area, rural inhabitants have to travel greater distances. The scarcity of transportation is also a harsh reality. In developing countries, people have to walk long distances or use improvised transportation to reach a health care facility.

An important outcome associated with spatial access is utilization of health services. By increasing access to health facilities, people who need these services the most will most probably utilize. But an important caveat must be noted. Increasing the number of physical facilities on the ground does not necessarily translate to greater utilization. It is the complex interplay of human and social factors, geographic or spatial characteristics as well as the physical locations of these facilities that ultimately determine the utilization levels.

Measures of spatial accessibility can be classified under four categories: (1) provider to population ratio, (2) distance to nearest provider, (3) average distance to a set of providers, and; (4) gravitational models of provider influence. For this study, the Euclidian distance between centroids was used as distance measures. This is due to the unavailability of a complete map of the city’s street network.

1.1.3 Location Allocation Models

A location model is a mathematical optimization technique that evaluates whether a site should opened, or whether an existing facility should closed, or where a new facility should be located based on costs and constraints (Junthirapanich and Pratheepthwaveephon, 1998). Proximity is one of the fundamental aspects of location analysis (Marianov and Serra, 2004). Essentially, it is assumed that clients are more likely to go to facilities that are closest in proximity. Coverage models work under the assumption of “acceptable proximity”. Given a preset distance, coverage is achieved when the proximity between a demand point and the candidate facility site is less than or equal to this value. Coverage models either minimize the number of facilities needed to cover all of the demand points (set covering) or maximize population coverage given a fixed number of facilities (maximum covering). In contrast, center models locate facilities to minimize the coverage distance such that each demand node is covered within the endogenously determined distance by one facility (Daskin, 1995). Median models, on the other hand, minimize the weighted distance between demand-facility pairs given a fixed number of facilities to be located.

Models that deal with a hierarchical network of facilities are considered a subset of location models. There is extensive literature on hierarchical location-allocation model including those by Moore and Revelle (1982), Eitan, et al (1991) and Daskin (1995). An example of a private sector application is in the banking industry, where there is a need to locate ATMs and bank branches
simultaneously. ATMs offer a limited menu of services while a bank branch may offer more services. On the other hand, a public sector application involves locating schools within the school system where there is a need to locate primary, middle and high schools. Although the population that they serve as different, there are linkages between these facilities that make them hierarchical in nature. Hierarchical service systems also exist in regionalized health services, distribution networks, community extension programs, and in many other public facility and service systems (Moore and ReVelle, 1982)

There are 2 common approaches to a hierarchical location-allocation problem. One is a variant of the maximum covering model and the other is a variant of the p-median model. A hierarchical covering model provides insights on the proportion of the population that could be served by these facilities when constrained by distance or travel time. An example would be in locating a hierarchical network of police stations and outposts where population coverage is constrained by response time or distance. In contrast, the hierarchical median model minimizes the total weighted distance or time the population must travel in order to reach a particular facility. The model shows the average distance that a person in the network must travel in order to reach the facility s/he is assigned to.

Another approach to modeling location allocation problems is the use of gravity models. Gravity models attempt to represent the potential interaction between any population point and all service points within a reasonable distance, discounting the potential with increasing distance or travel impedance (Guagliardo, 2004). An important component of the gravity model is the distance decay coefficient ($\beta$). The tendency for increased distance or travel cost to mitigate the mount of travel to a given destination is termed distance decay (Hodgson, 1981). An alternate way of understanding the concept of distance decay is that it is the elasticity of the relationship between distance and demand. This is consistent with the findings presented in the previous section on the relationship between distance and service utilization, including health care services.

Hodgson (1988), posts that other than distance, facility attractiveness also plays an important factor in a client/patient’s decision to patronize a facility. Although distance from a facility is negatively related to utilization, factors like facility size, quality of service and waiting time have positive effects on utilization behavior. In the hierarchical location allocation model he proposed for a primary health care delivery, he integrated both a distance decay coefficient ($\beta$) as well as a coefficient that quantifies the attractiveness of facility size ($\alpha$). Ideally, these coefficients are intuitive and logical especially for areas where there is a wide range of choices available for a health consumer. But it also requires extensive empirical investigation in order to capture the true values of
one or both of these values. It also has limitations. These include the nature of the illness, the quality of care and social and wealth status, and the relationship of the patient to the physical of health facility (social distance) (Buor, 2002). These factors are not fully captured in these models.

Despite the value-added in using a gravity-type model for this study, there is considerable insight that could be gleaned from the use of a “classic and simple” hierarchical median formulation. For example, Oppong and Hodgson (1994) in a study of the Suhum District, Ghana asserted that results of “their study indicate that simple applications of location-allocation models provide important information for general spatial decision-making and data limitations do not preclude their application in the Third World”. Although the health district being studied was hierarchical in nature, the p-median formulation used was not the hierarchical median model. Despite this, they were able to show that average weighted distance (AWD) to health facilities decreased as the number of facilities to be located increased. But the marginal returns to increases in accessibility, measured by decreasing average travel distance, decreased as more facilities were added to the system. Their results also indicate that the AWD of the current system (AWD =1.38 kms.) could be achieved with a smaller number of facilities (p=23 facilities). By using a hierarchical median model, I believe that the computational results would show a similar trend. By simultaneously locating community health facilities, the accessibility of health programs offered in different types of facilities is increased.

An important component to location-allocation models, including hierarchical location-allocation models, is the estimation of demand for these facilities (or the services they offer). There was only one health literature that specifically looked into how demand for health services could be measured or estimated. In a recent study by Griffin, et al (2006), they presented a “process for estimating health care need within individual geographical areas from publicly available data.” Using the survey component of the 1999-2002 National Health and Nutrition Survey, the presence or absence of a health condition was regressed with self-reported general health, controlling for appropriate socio-demographic factors. The coefficients generated formed the base multiplier in generating estimated demand levels. The estimated demand levels where then used as inputs in an optimization model that maximized demand weighted coverage. For developing countries, estimating and forecasting demand for health services is especially challenge since the availability of a sophisticated dataset similar to the one used by Griffin, et al (2006) is highly unlikely.

Another important component to modeling access is the underlying road network that connects facilities. To maximize accessibility, facilities are optimally located using location-allocation models such as those described above. But these models assume that the road infrastructure is static and always available (Murawski and Church, 2006). In a study by Murawski and Church (2006), they
were able to show that significant improvements in accessibility could be achieved by holding the existing network of rural health facilities and constrained by a budget. This model is applicable to developing countries where it might be more politically judicious to improve some of the roads connecting communities to existing health facilities than to add or remove or downsize existing facilities.

1.2 MAIN FINDINGS

Two hierarchical location-allocation models were implemented to gather insights into the optimal configuration of a network of community-based health facilities. These optimization models were used to locate facilities in the rural and urban areas separately and in the city as a whole.

Assuming no capacity constraints, the number of BHCs in the models is likely to be sufficient to meet the current demand level for health care. This can be seen in the 100% coverage achieved when the base case was computed. But the challenge inherent in this problem lies in the location of these facilities. Their current location, particularly in the rural region, has led to disparities in the delivery of health services. A considerable number of facilities are located in the urban area which leave rural residents disproportionately unable to fully access these health services. By optimally locating health facilities, computational results indicate that current system could be improved, even without adding a new facility. Over and above this, even greater social and economic benefits could be derived with a network of fewer facilities while maintaining the same level of service coverage.

Sensitivity analysis indicate that locating a smaller number of BHCs and HNPs generates significant cost-savings on the part of the local government. The performance of these alternative configurations, in terms of average distance traveled and population coverage, are equal or better than the current system.

On the other hand, there are cost trade-offs to this. A network with a relatively smaller number of facilities is cheaper but, at the same time, creates more financial burden on the clients. Clients have to farther to reach facilities. This leads to higher out-of-pocket costs and opportunity costs on the part of the client.

1.3 PROCEEDING SECTIONS

Section 2 of this paper will provide a brief introduction of Davao City and its health system. Section 3 contains discussion on the two model formulations. Section 4 presents computational results for both models as well as the sensitivity analysis. The last section discusses the conclusions and model extensions.
THE STUDY AREA

The Republic of the Philippines is an archipelago located in Southeast Asia. It counts Indonesia, Malaysia, and Brunei Darussalam as its closest neighbors and trade partners. Unlike the United States’ federal form of government, local government units govern over provinces, municipalities and cities. The country is divided into different provinces. Each province is divided into municipalities and cities. Cities are municipalities that have been “upgraded” because of the increased economic activity in the area as exemplified in the increase in local tax collection. The smallest geo-political unit in a local government is the barangay.

Since 1991, a number of national programs, including health care, were devolved to the local government level. This means that these programs will be funded and administered by the local governments. Financing of public services is a mix of local and national funds. Local funds come from local tax and fees collection. National funds come in the form of Internal Revenue Allocations (IRA). The IRA is computed based on the local government’s income classification. A local government’s IRA is directly proportional to its population, tax collection, level of economic activity. Consequently, richer municipalities and cities enjoy a larger IRA compared to poorer municipalities.

The study area is Davao City, a metropolitan city in the southern tip of the country covering an area of 24,400 square kilometers (9,420.9 square miles). In 2000, the city’s total population was pegged at 1.1 million people spread over 180 barangays. Barangays are the smallest geo-political unit in a city or municipality. Although the is comparable to the state of Vermont (9,250 square miles) in terms of geographic area, Davao City has close to twice the population of Vermont. While Davao has 180 barangays, Vermont only has 14 counties. This shows that there are significant administrative burdens on the part of the local government when it comes to managing that many barangays compared to a state government that oversees only 14 counties.

Figure 2 illustrates the city’s population distribution and population density. Most of the population is concentrated in the city’s urban center.
which is along the coast. In terms of proportion, there are more heavily populated urban barangays compared to the rural north. Although there are rural barangays that have higher population, a larger number of the rural barangays are not heavily populated. This is supported when one looks at the city’s population density. The population densities for barangays in the rural north are less than 1 person per square kilometer. This can be attributed to the fact that rural barangays are bigger in terms of area but are less populated.

The distribution and density of population has a significant impact on the health system. Barangays with low population densities make it less attractive to private and public investments in health infrastructures (i.e. hospitals, clinics). This creates a disparity because most of population that lives in this part of the city is poor. They are also more likely to be dependent on public health care services and infrastructures compared to the rest of the population.

Other than the city-run hospitals, the focal point in the delivery of health programs and services is the Barangay Health Center (BHC). There are 120 BHCs located in 180 barangays. Figure 3 shows the location of the BHCs in relation to the total barangay population. BHCs are disproportionately located in the central city and nearby neighborhoods. Most of the BHCs (85%) are in the urban center and the surrounding suburban area. This is not surprising since most of the population reside in these areas. This imbalance in distribution and location of BHCs across urban and rural areas has significant implications on their access to health facilities. It appears that health programs and services are more accessible to the urban residents compared to their rural counterparts. They would also have more choices in terms of facilities. They can go to the BHC in their own community or in another barangay. They could also opt to go to private clinics and hospitals. But as one goes farther north, there are lesser BHCs on the ground.

Figure 3. Location of Barangay Health Centers in Davao City, 2004.

Figure 4. Number of Nurses per BHC, 2004.
The people in the rural areas face significant barriers to access. The major highway that cuts through this northern region, the Bukidnon-Davao Highway, is built on a mountainous part of the city. As can be seen in Figure 3, there are some BHCs that are located near this highway. The topographical make-up of this region makes traveling from the community to the highway difficult and expensive. As one leaves the highway, a commuter has to ride a “habal-habal” (an altered motorcycle) or a horse-driven cart to reach far-flung communities which is charges more because it is illegal. Far-flung communities are oftentimes very far from the highway that it takes a couple of hours to reach them. One of the observations shared by the director of the City Health Office is that these people often wait until they get really sick before they go to the health center or a hospital.

A registered nurse or a licensed midwife manages a BHC. They are assisted by volunteer Barangay Health Workers. Figure 4 shows the location of BHCs and the corresponding number of nurses that are present in these centers. In the urban and suburban areas of the city, the BHCs are close to each other so the area of influence of these BHCs overlaps. But in the rural regions, the opposite condition persists. Having lesser BHCs leads to a fewer number of public health professionals available for consultations. Due to the distance of some communities to the BHC, the nurse or midwife would travel to these communities themselves. According to City Health estimates, there are communities that take 8 hours of walking (one-way) to reach. The nurse or midwife will then have to stay overnight in the community to serve the people there then walk back the following morning. This is a difficult burden on the part of the health professionals as well as on the health system itself because the BHC is left unattended when the nurse/midwife leaves for these communities.

The number of nurses/midwives in a BHC that serves 1,000 residents supports the findings given above. This is a very crude approximation of the WHO indicator (ratio of nurses to 10,000 people) but it gives an insight on the availability of health professionals to meet the health needs of 1,000 people. Figure 5 shows this ratio across the different barangays. The smaller maps show this ratio in the downtown area. As can be seen in the maps, 6 barangays in Paquibato district do not have nurses. This is because there are no BHCs located in these barangays, each of which has a population of less than 40,000 people. In contrast, there are also barangays in the urban center.
(Health Districts A, B, C and D) that do not have nurses. But people in these communities can easily go to another Barangay that has a BHC or go to a private clinic or hospital. The sharp contrast between the communities in the rural north and those in the urban center shows another angle to the disparity in the delivery of health services and programs as well as in the community’s ability to “consume” these services and programs. The northern regions of the city are sparsely populated and poor communities distributed over a wide geographic area and, at the same time, suffer from a disproportionately small number of BHCs.

Other than the BHCs, the Health and Nutrition Posts (HNPs) is another community-based facility run by the city. According to the City Health Office, these facilities serve as staging points for Information, Education and Communication (IEC) activities for the city’s nutrition program. It also serves as an extension to BHCs. Ideally, it is supposed to “host” programs such as feeding programs, Operation Timbang (weighing program) and growth monitoring depending on the need of the surrounding population. It is also heavily involved in health promotions. In contrast to BHCs, these facilities are managed by volunteer health workers, mothers and a nutrition scholar. It is funded partly by the city and the barangay itself. At present, the city plans to operate 54 HNPs in the city. But whether they are operational or their actual location is unknown.

An important component to the local health system is the level of public financing that is an indicator of the local government’s commitment towards health care. Financial statistics contained in Figure 6 are based on the budgetary allocations made by the Davao City government from 1986 to 2000. The graph shows that the amount of money that the government allocates for the health system is increasing. Although the budgetary allocation to health care has been increasing, its proportion to the city’s total budget has been decreasing. In 1986, the health budget comprised 56% of the total budget of the city. Fourteen years after, this proportion has dropped to only 8%. Other than investing in a rabies center in 2002 and building another city hospital 2004, there have not been any significant investments in the health infrastructures. According to the City Health Office, a number of health centers have been closed due to the lack of financial resources to sustain all health centers. This situation shows that the health
system cannot expect any significant investments in the future as well. Given a limited financial resource, the local health system is faced with the challenge of equitably and effectively delivering health programs and services to all its constituents.

3 MODEL FORMULATION, COMPONENTS AND ASSUMPTIONS

3.1 Model Assumptions

In developing the models used in this study, the following assumptions were made:

1. There are no facilities of any located on the ground. Although unrealistic, this allows for a comparative analysis between the current system and other configurations of the system.

2. The facilities to be located will be built in the barangay centroid, which is theoretically the geographic center of the community. This is a very strong assumption because existing facilities are not necessarily located in the barangay centroid. This also assumes that the people in the community live in and around the barangay centroid.

3. The lack of a comprehensive road network map for the city was a limiting constraint in developing the model. The use of Euclidian distances does not capture the true travel behavior of health consumers in the city. It also constrains the analysis on the actual distance traveled; travel time and costs would affect consumer behavior.

4. The overhead cost of each type of facility is the same regardless of where it is located. The annual overhead costs for a BHC is assumed to be PhP 1,000,000. This is based on the expenditure schedule for the Ma-a BHC, which is assumed to be representative of most BHCs. On the other hand, the overhead cost for HNPs is assumed to be much smaller (half of the annual overhead costs of a BHC). At present, there is no readily available data that shows the expenditure patterns for both BHCs and HNPs.

5. The demand metric used in this study is a crude measure since it automatically assumes that every person in the community demands these services. This is unrealistic because there are other factors that can influence demand including availability of alternative health facilities, health status, unmet health needs, etc. It also does not differentiate the health needs of each person in the community against the services offered.

3.2 Model components

3.2.1 Facility and Service hierarchy

The hierarchy of facilities envisioned for this study is a 2-tier system composed of Health and
Nutrition Posts (type-1 facility) and Barangay Health Centers (type-2 facility). As the lowest type of facility, the HNP offers only a limited menu of health services (type-1 service). For the purposes of this study, the HNPs are assumed to offer health services that target children aged 0 to 5 and women of reproductive age. On the other hand, the BHC offers the complete menu of health services (type-2 service).

3.2.2 Demand Estimates

The demand metric used for both models was the total barangay population count from the 2000 Census. The demand for BHC services is the total barangay population. On the other hand, the demand for HNP services is only a fraction of the barangay population. To estimate this, the factors used by the City Health Office to determine the eligible population were utilized. The CHO assumes that the 3% of the total barangay population comprise the target population for the immunization program (children aged 0 to 5) while 3.5% of the total population is target clients of the maternal and child health program (women of reproductive age).

3.2.3 Distance Estimates

The distance metric used in both models was the Euclidian distance between the Barangay centroids. Barangay centroids were generated using a VB Script in ArcGIS. A distance matrix was then generated using another VB Script that was developed by Li Zou (see http://arcscripts.esri.com/details.asp?dbid=13957). The matrix generated contained the centroid to centroid Euclidian distances.

3.3 Model Formulations

3.3.1 Hierarchical Coverage Model (HCM)

The HCM maximizes the total population that is considered “covered” by the hierarchical network of facilities. Given a fixed coverage distance and fixed number of facilities to locate, the model seeks to locate different type of facilities within the network to maximize coverage. The model is not “forced” to cover all of the population. The coverage distance and the number of facilities to locate are binding constraints that limit the proportion of the population that is covered. The HMM formulation is as follows:

- Indices
  
  - \( q \) Type of facility (1,2)
  - \( i \) Demand node
  - \( k \) Type of service (1,2)
  - \( j \) Candidate facility site
• Inputs

\[ a_{kj} = \begin{cases} 1, & \text{if type 1 facility located at site } j \text{ can provide type } k \text{ services to demand } i \\ 0, & \text{otherwise} \end{cases} \]

\[ b_{ik} \quad \text{demand for type } k \text{ services at node } i \]

\[ P_q \quad \text{number of type } q \text{ facilities to locate} \]

\[ D_q \quad \text{coverage distance for type } q \text{ facilities} \]

• Decision Variables:

\[ X_q = \begin{cases} 1, & \text{if locate type 1 facility in site } j \\ 0, & \text{otherwise} \end{cases} \]

\[ Z_{ik} = \begin{cases} 1, & \text{if demand for service } k \text{ at node } i \text{ is covered} \\ 0, & \text{otherwise} \end{cases} \]

• Objective function

\[
\text{Maximize } \sum_i \sum_k b_{ik} Z_{ik} \quad (1)
\]

• Subject to:

\[
\sum_j X_{jq} = P_q \quad \forall q \quad (1.1)
\]

\[
Z_{ik} \leq \sum_j a_{kj} X_{jq} \quad \forall i, k \quad (1.2)
\]

\[
0 \leq Z_{ik} \leq 1 \quad \forall i, k \quad (1.3)
\]

\[
X_{jq} = 0,1 \quad \forall j, q \quad (1.4)
\]

\[
Z_{ik} = 0,1 \quad \forall i, k \quad (1.5)
\]

The types of services (k) are different from facility types (q). In this study, there are 2 distinct types of facilities: Barangay Health Centers (BHCs) and Health and Nutrition Posts (HNPs). HNPs offer a limited menu of health programs (k=1) while BHCs offer the full-range of health programs (k=2) where the programs offered by the HNPs are administered plus other health programs.

The objective function for this model maximizes the number of covered demand by the type k services offered. Constraint 1.1 limits the number of each type of facilities to the pre-determined number of each type of facility to be located. In Constraint 1.2, there must be at least one facility that offers service k that is located within the coverage distance, for a demand for service k at node I to be considered “covered”. Constraint 1.3 is the non-negativity constraint while Constraints 1.4 and 1.5 ensure that the decision variables are binary.
3.3.2 Hierarchical Median Model (HMM)

The HMM minimizes the demand-weighted distance from the demand nodes to the facility sites. It is a variant of the p-median model applied to a hierarchical network of facilities. Since a “coverage distance” does not constrain the model, demand nodes are assigned to the closest facilities in such a way that the over-all demand-weighted distance for the whole network of facilities is minimized.

The health system under consideration in this study is a globally inclusive service hierarchy with a successively inclusive facility hierarchy. The services offered in a HNP are also offered in a BHC. The demand population for HNP services is a sub-set of the total barangay population, which is target population for services offered in the BHCs. The p-median formulation presented below reflects this relationship.

- **Indices**
  - \( k \) Type of service and facilities (1,2)
  - \( i \) Demand node
  - \( j \) Candidate facility site

- **Inputs**
  - \( b_{ik} \) demand for type \( k \) services at node \( i \)
  - \( d_{ij} \) distance between node \( i \) and candidate site \( j \)
  - \( p_k \) number of type \( k \) facilities to locate

- **Decision Variables**:
  \[
  X_{jk} = \begin{cases} 
  1, & \text{if type } k \text{ facility is located at candidate site } j \\
  0, & \text{otherwise} 
  \end{cases}
  \]
  \[
  Y_{ijk} = \begin{cases} 
  1, & \text{if demand at node } i \text{ for type } k \text{ services are satisfied by locating a type } k \text{ facility at site } j \\
  0, & \text{otherwise} 
  \end{cases}
  \]

- **Objective function**
  \[
  \text{Minimize } \sum_i \sum_j \sum_k b_{ik} d_{ij} Y_{ijk} \quad (2)
  \]

- **Constraints**
  \[
  \sum_j Y_{ijk} = 1 \quad \forall i, k \quad (2.1)
  \]
\[
\sum_j X_{jk} = P_k \quad \forall q 
\] (2.2) 

\[
Y_{ijk} \leq \sum_{h=k}^{m} X_{jh} \quad \forall i, j, k 
\] (2.3) 

\[
X_{jk} = 0, 1 \quad \forall j, q 
\] (2.4) 

\[
Y_{jk} = 0, 1 \quad \forall i, k 
\] (2.5) 

The objective function for HMM minimizes the total demand-weighted distances. Constraint 2.1 ensures that the demand at node I for type k services is assigned to exactly one facility located at candidate site j. Constraint 2.2 makes sure that the total number of type k facilities located does not exceed the pre-determined number of facilities for each type of facility. Constraint 2.3 ensures that the demand at node I for type k services is assigned to a facility that offers this service – either type k or k+1 facility - located in candidate site j. Constraints 2.4 and 2.5 assign binary variables to the decision variables.

4 RESULTS AND DISCUSSION

Using the two hierarchical location-allocation models illustrated above, different ways of optimally locating BHCs and HNPs across the rural and urban regions of the city as well across the whole city were explored. This methodology was adopted to illustrate the gains that could be made in using either HMM or HCM. The different analyses done for this study are outlined in the Table 1.

For each set of analysis, the population coverage for type 1 (HNP) and type 2 (BHC) services as well as the average weighted distance (AWD) a “covered” or “assigned” client must travel to avail of these services. Population coverage is computed based on the coverage distance metrics used in the models. For consistency, barangays that are within the HNP coverage distance from located BHC are added to the population coverage for HNP services when HCM is used.

There is also a distinction between the AWD values generated for each model. The AWD values generated using the HMM is the average distance that a client travels to avail of a particular type of service (services in the HNP or BHC) in the facility that s/he is assigned to. Since the model assigns demand nodes to facility sites, the computed AWD values represents average distance

<table>
<thead>
<tr>
<th>Geographic Region</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>Compare &quot;split&quot; and unsplit barangays</td>
</tr>
<tr>
<td>Rural</td>
<td>Compare &quot;split&quot; barangays across models</td>
</tr>
<tr>
<td>Urban</td>
<td>Compare urban barangays across models</td>
</tr>
<tr>
<td>City</td>
<td>Compare the use of different models for each region and the use of a single model for the whole city</td>
</tr>
</tbody>
</table>

Table 1. Comparative analyses on Davao City barangays
traveled for each client in the whole network because the model assigns all demand points to a specific facility site.

In contrast, the AWD values generated using the HCM represents the average distance that a covered client (client that is within the coverage distance) travels to avail of a particular service. This is only crude estimation since the model itself does not assign demand points to facility sites.

4.1 Comparative analysis of split and unsplit rural barangays

At present, there are 27 rural barangays. A big obstacle to the analysis of this region is that the barangays cover wide expanse of land. The use of the barangay centroids based on the original barangay configuration is not realistic. It does not reflect the distribution of the population within each barangays. To assume that most of the residents reside on and around the geographic center is unrealistic. At the same time, a uniform population distribution cannot also be assumed. Figure 7 shows that BHCs are not necessarily located on or very near the barangay centroid.

It can be assumed that these health facilities are located where the settlements are. Therefore, it is more likely that the facilities are located where most of the population lives. Another key assumption is that a significant portion of the population lives near the highway. Given these assumptions, a systematic method of “splitting” the barangay to smaller geographic areas based on their relative proximity to a BHC and/or the national highway. Using ArcGIS (v.9.2), a 3-kilometer buffer zone was created around these infrastructures. This then served as a basis for clipping the original boundaries. Using the Erase function created by Susan Jones (see http://arcscripts.esri.com/details.asp?dbid=14625) Population was then redistributed across the newly created barangays. It is assumed that 70% of the population lives near the areas closer to these infrastructures. The newly-create barangays are illustrated in Figure 8. There were 21 new barangays generated using this methodology. The boundaries outlined in a heavier line are the original boundaries while the lighter lines mark the new barangay boundaries within the original
boundary.

By using both the HCM and HMM on the split and unsplit barangays, computational results are presented in Table 2. In this instance (base case scenario), the actual number of BHCs (18) and HNPs (0) that are on the ground were used. The coverage distance used is 5 kilometers for BHCs and 2 kilometers for HNPs. This network would cost the local government PhP 18 Million to operate.

In terms of coverage, the percentage of the population that is covered in the split barangays version is relatively lower than when the unsplit barangays was used, especially for the HNP coverage. The HMM implementation on the two sets of barangays also yielded varying results. Clients in the split barangays travel longer distances compared to the unsplit barangays. It is likely that the AWD and population coverage values generated when the barangays are split reflects the true situation on the ground. Although these models are implemented on the strong assumption that there are no facilities on the ground, the computational results show that there is a significant fraction of the population that will not be covered by a health facility. This is particularly true for HNP coverage, which is envisioned to be in the frontline in providing select health services that a community needs. Since only BHCs were located in this scenario, people have to go to these facilities to avail of the health services that they need the most. This translates to longer travel distances. With people having to travel farther, they are less likely to visit a BHC. This creates an unhealthy outcome for the people living in this area.

Table 2. Computation results for the base case

<table>
<thead>
<tr>
<th>BASE CASE</th>
<th>Unsplit Brgys</th>
<th>Split Brgys</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coverage</td>
<td>Median</td>
</tr>
<tr>
<td>HNP Cost per Capita (PhP)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BHC Cost per Capita (PhP)</td>
<td>211.92</td>
<td>212.42</td>
</tr>
<tr>
<td>Population covered by HNP @ coverage distance</td>
<td>4,211</td>
<td>5,045</td>
</tr>
<tr>
<td>Population covered by BHC @ coverage distance</td>
<td>84,036</td>
<td>84,730</td>
</tr>
<tr>
<td>% of HNP coverage @ 2k</td>
<td>74.7%</td>
<td>89.5%</td>
</tr>
<tr>
<td>% of BHC coverage @ 5k</td>
<td>97.9%</td>
<td>97.7%</td>
</tr>
<tr>
<td>AWD for HNP</td>
<td>0.11</td>
<td>0.50</td>
</tr>
<tr>
<td>AWD for BHC</td>
<td>1.62</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Compared to the actual locations of BHCs in this area (Figure 7), the spatial configuration generated in this scenario can be considered as an improvement. But it also highlights the inequities that result given the actual configuration of facilities. The lack of road networks as well as the distances between settlements and health facilities makes accessing the services difficult, especially for those who live in far-flung, isolated parts of the barangay.
4.2 Comparative analysis of split rural barangays using HMM and HCM

Using the split barangays, HMM and HCM were implemented using different values for the number of HNPs and BHCs to be located. The values used were based on a “toy model” implementation conducted a few months ago where these models were implemented in a sub-set of barangays that approximates the geographic and demographic characteristics of the city. The computational results are in Table 3.

Table 3. Computational results for HCM and HMM implementation on split rural barangays

<table>
<thead>
<tr>
<th></th>
<th>SCENARIO #1</th>
<th>SCENARIO #2</th>
<th>SCENARIO #3</th>
<th>SCENARIO #4</th>
</tr>
</thead>
<tbody>
<tr>
<td># of HNP</td>
<td>Median</td>
<td>7</td>
<td>13</td>
<td>25</td>
</tr>
<tr>
<td># of BHC</td>
<td>Median</td>
<td>3</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Total Cost (PhP)</td>
<td>6,500,000.00</td>
<td>12,500,000.09</td>
<td>29,500,000.00</td>
<td>30,000,000.00</td>
</tr>
<tr>
<td>Total HNP Cost (PhP)</td>
<td>3,500,000.00</td>
<td>6,500,000.00</td>
<td>12,500,000.00</td>
<td>15,000,000.00</td>
</tr>
<tr>
<td>Total BHC Cost (PhP)</td>
<td>3,000,000.00</td>
<td>8,000,000.00</td>
<td>8,000,000.00</td>
<td>15,000,000.00</td>
</tr>
<tr>
<td>HNP Cost per Capita (PhP)</td>
<td>1,132.54</td>
<td>1,013.72</td>
<td>1,548.26</td>
<td>1,508.70</td>
</tr>
<tr>
<td>BHC Cost per Capita (PhP)</td>
<td>80.89</td>
<td>64.13</td>
<td>109.82</td>
<td>90.51</td>
</tr>
<tr>
<td>Population covered by HNP @ coverage distance</td>
<td>3,000</td>
<td>3,652</td>
<td>1,996.29</td>
<td>4,000</td>
</tr>
<tr>
<td>Population covered by BHC @ coverage distance</td>
<td>33,407</td>
<td>40,777</td>
<td>59,030.19</td>
<td>64,100</td>
</tr>
<tr>
<td>% of HNP coverage @ 2K</td>
<td>50%</td>
<td>0%</td>
<td>74%</td>
<td>70%</td>
</tr>
<tr>
<td>% of BHC coverage @ 6K</td>
<td>30%</td>
<td>54%</td>
<td>63%</td>
<td>74%</td>
</tr>
<tr>
<td>JWD for HNP</td>
<td>2.34</td>
<td>0.95</td>
<td>0.95</td>
<td>0.12</td>
</tr>
<tr>
<td>JWD for BHC</td>
<td>6.89</td>
<td>1.92</td>
<td>3.78</td>
<td>2.33</td>
</tr>
<tr>
<td>2.85</td>
<td>2.52</td>
<td>1.17</td>
<td>1.94</td>
<td></td>
</tr>
</tbody>
</table>

If a comparable mix of facilities were to be located (13 HNPs and 6 BHCS), the network’s total operating cost is only PhP 12.5 Million, which is 30% cheaper than the base case (0 HNPs and 18 BHCS). This is a substantial savings on the part of the local government. But there is significant positive and negative trade-off for each facility type. Population coverage for HNPs increases while coverage for BHC decreases significantly. But, over-all, this is still acceptable since the spatial distribution of the facilities show that there are facilities that are located in the inner parts of the barangays (Figure 9 and 10). The dots represent the current (and actual) BHC locations. The triangles represent the optimal location of HNP and BHC facilities. Configurations generated by both HMM and HCM show there are facilities that were located very near the current location. But what is significant is that there are facilities are located in more isolated parts of the region – farther away from the national highway as well as nearer the city’s northern boundary. Although

Figure 9. Location of current BHCs and the new network of facilities (using HCM)
the over-all coverage is relatively lower, people that reside in this part of barangays have greater access to services, regardless of whether it is only a limited range of services. A more equitable access to health services is created. This is preferable to having less incentive to avail of the services because the current location of the facility is too far.

For the new network, the average distance that a person travels a relatively shorter distance to avail of HNP services and relatively longer distances to BHC services compared to the base case. This is evident in the AWD values generated using HMM. The same pattern could be seen in the average distance traveled by clients within the coverage distance for HNP and BHC services. With more facilities that are located in the interior of the rural region, people that live close to these facilities can easily avail of the services.

Despite low population coverage, significant gain in enhancing equitable access to health care is achieved. The people who live in the more isolated and far-flung parts of the region would enjoy greater access to health services which they would not enjoy in the current system.

Table 3 also shows the sensitivity analysis results. It shows the changes in population coverage and AWD when the number of facilities for each type is increased. As more facilities are located, the proportion of the population that is covered increases as well. Given the large area under consideration, considerable resources must be invested to increase coverage. To reach more people, more facilities must be located.

When considering the whole system, the average travel distance of each person is decreases as well. This is evident in the downward sloping solid line in Figures 11 and 12. This is expected because, with more facilities, one travels a shorter distance to avail of services. On the other hand, the average travel distance the covered population increases slightly as more facilities are located (broken lines). This can be attributed to the fact that there are less people traveling longer distances.

Although Figures 11 and 12 are not Pareto curves,
it provides an insight on which facility mix are dominated alternatives. Scenario 2 and 3 are dominated. Significant gains in terms of average travel distances and population coverage could be achieved by locating more facilities.

But, it is also important to keep in mind that locating facilities does not happen in a vacuum. It is done within a political and financial context. By locating more facilities, the total operating cost increases. The gains achieved in terms of greater accessibility and equity must be weighed against the cost that it takes to achieve it. In the minimum configuration (Scenario 1), it costs less than PhP 100.00 investment to reach each person in the system. But they have to travel a longer distance to avail of the services which translates to higher out-of-pocket costs on the part of the client. On the other hand, the maximum configuration (Scenario 4) entails a public investment close to PhP 200.00 per person to achieve 100% coverage. In this network, clients travel less than 0.1 kilometers to avail of HNP services and between 1.0 to 2.0 kilometers to avail of BHC services. Ultimately, the number of facilities as well as its configuration influences the distribution of costs between the local government and the clients themselves.

4.3 Comparative analysis of urban barangays using HMM and HCM

There are 157 barangays in the urban region. These are the barangays that are in the downtown area and the surrounding suburbs. The computational results for the HCM and HMM implementation are in Table 4.

Table 4. Computational results for HCM and HMM implementation on urban barangays
The current configuration of BHCs in the urban region is shown in Figure 13. At present, there are 102 BHCs in the region. Almost all of the barangays have a BHC. There are instances where barangays have more than 1 BHC. This forms the base case for this analysis.

Using the base case, HCM and HMM results indicate that 100% of the target population for BHC services is covered while a lesser proportion of the target population for HNP services is covered. A client travels less than 2 kms to avail of BHC services and less than 1 kilometer to get HNP services. Given the short distances between facilities, clients can also avail of services from BHCs in other barangays. There are no restrictions on where a person could access these services. The results of the base case show that there are enough facilities on the ground to fully serve the population.

But the sensitivity analysis conducted using different HNP and BHC combinations indicate the same level of performance could be achieved (Table 4). Scenario 1 locates more facilities (100 HNP and 50 BHC). This network is PhP 2 Million cheaper than the current system and covers more of the eligible population for HNP services. In contrast, Scenario 2 locates half the number of facilities from the first scenario but costs almost PhP 50 Million cheaper than the base case (Figure 14 and 15). On a per capita basis, the cost per capita for Scenario 2 is half of the cost needed for Scenario 1. This means that, given a smaller number of facilities to locate, the local government would be spending less on a per capita basis. This supports the overall cost savings that is generated when alternative facility combinations were used.

Although the AWD values change across the different scenarios, the incremental changes are
very small. This shows that the change in the average distance that a client must travel within the network does not change significantly to affect their utilization of these services. By locating a smaller number of facilities simultaneously, the

Scenario 1 and 2 could be seen as the maximum and minimum (respectively) of the range of facility combinations that would perform equally or better than the base case. But this must also be put in the context of local politics. Community-based health facilities serve as political currency. Closing or re-designing current health facilities might have political repercussions that local politicians might be unwilling to take on.

4.4 Comparative analysis of all barangays using HMM and HCM

The last step to this study was to show how community-based health facilities would be located for the whole city using HMM and HCM. Two approaches were used. One was to locate facilities using HMM across all of the barangays. For the latter, the barangays used was generated by merging the split rural barangays and the urban barangays. This brings the total number of barangays to 205 from the original 180. The other approach involved implementing different models on the rural and urban regions of the city. HMM was used on the split rural barangays while HCM on urban barangays.

Figure 3 illustrates the current location of BHCs across the city’s barangays. It can be seen that a large number of the BHCs are located in the urban area. Eighty-five percent (85%) of the BHCs are located in the urban area.

Locating 120 BHCs and 0 HNPs for the whole city serves as the base case. If HMM was used to locate the base case, the configuration is shown in Figure 16. The dark colored dots show the new location of the facilities. Other than the fact that the model locates at the centroids rather than on the actual locations of existing facilities, it locates more facilities in the rural area compared to the actual number of facilities in this area. In this alternative configuration, there are 22 BHCs that are located in the rural area. A number of these facilities are located in the interior of the area rather clustering nearer the suburbs.

For this configuration, population coverage is 97% for HNP services and 100% for BHC services (Table 5). The average travel distance is 0.13 kilometers. Although this does not hold for the rural barangays, the alternative configuration locates BHC closer to a larger proportion of the rural population, especially...
those that live in the interior barangays. They would still walk longer distances compared to their urban counterparts and those living near the highway but they do not have to walk as far as the distance they are travelling in the current configuration. This shows that, even without adding a single facility, significant gains could be achieved when facilities are optimally located. This configuration costs the same as the status quo. But it provides greater access to people living in more far flung area.

Table 5. Computational results for HCM and HMM implementation on all barangays

<table>
<thead>
<tr>
<th></th>
<th>BASE CASE</th>
<th>SCENARIO #1</th>
<th>SCENARIO #2</th>
<th>SCENARIO #3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Barangays</td>
<td>Rural Barangays</td>
<td>Urban Barangays</td>
<td>All Barangays</td>
</tr>
<tr>
<td># of HNP</td>
<td>9</td>
<td>50</td>
<td>18</td>
<td>35</td>
</tr>
<tr>
<td># of BHC</td>
<td>125</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Total Cost (PHP)</td>
<td>120,000,000,000</td>
<td>140,000,000,000</td>
<td>160,000,000,000</td>
<td>180,000,000,000</td>
</tr>
<tr>
<td>Total HNP Cost (PHP)</td>
<td>-</td>
<td>25,000,000,000</td>
<td>35,000,000,000</td>
<td>45,000,000,000</td>
</tr>
<tr>
<td>Total BHC Cost (PHP)</td>
<td>120,000,000,000</td>
<td>140,000,000,000</td>
<td>160,000,000,000</td>
<td>180,000,000,000</td>
</tr>
<tr>
<td>HNP Cost per Capita (PHP)</td>
<td>-</td>
<td>2,333.33</td>
<td>2,333.33</td>
<td>2,333.33</td>
</tr>
<tr>
<td>BHC Cost per Capita (PHP)</td>
<td>100,000</td>
<td>120,000</td>
<td>120,000</td>
<td>120,000</td>
</tr>
<tr>
<td>Population served by HNP @ coverage distance</td>
<td>73,128</td>
<td>25,041</td>
<td>5,267</td>
<td>9,358</td>
</tr>
<tr>
<td>Population served by BHC @ coverage distance</td>
<td>1,154,227</td>
<td>1,154,227</td>
<td>86,691</td>
<td>1,154,130</td>
</tr>
<tr>
<td>% of HNP coverage @ 9k</td>
<td>97%</td>
<td>100%</td>
<td>95%</td>
<td>54%</td>
</tr>
<tr>
<td>% of BHC coverage @ 9k</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>AMD for HNP</td>
<td>0.13</td>
<td>0.02</td>
<td>0.29</td>
<td>0.64</td>
</tr>
<tr>
<td>AMD for BHC</td>
<td>0.13</td>
<td>0.13</td>
<td>0.31</td>
<td>1.88</td>
</tr>
</tbody>
</table>

Table 5 summarizes the computations results from the sensitivity analysis implemented using different combinations of HNPs and BHCs. Scenario 1 is similar to the base except that it also locates HNPs at the same time. This is reflects the city’s current efforts in strengthening its health infrastructure. The distribution of BHCs across urban and rural regions is based on the actual distribution of existing facilities. The HNP distribution was set arbitrarily. The values used in the other scenarios were also set arbitrarily.

Figure 17 shows the side-by-side comparison of the two approaches to locating HNPs and BHCs for Scenario 1. Compared to the current configuration of existing facilities (Figure 3), this configuration, regardless of modelling approach, creates greater accessibility, thereby, creating a more equitable access to health services. This is because there are more facilities that are being located. Although the number of BHCs is the same, this implementation also located 50 HNPs. With more facilities to locate, the models are more likely to locate in more isolated parts of the city. But this
configuration has its drawbacks. It is more expensive.

But if one were to locate increase the number of HNPs while decreasing the number of BHCs (Scenario 2), there is a slight improvement in the performance metrics and, at the same time, it is slightly less expensive. The AWD to avail of HNP services is relatively shorter compared to Scenario 1. The AWD to BHC services, on the other hand, increased slightly. This could be attributed to the fact that people have to farther to avail of services that are not offered in HNPs. If HNPs are designed to be the frontline in delivering critical health services to vulnerable populations, this configuration could be a viable alternative.

In contrast, Scenario 3 explores the possibility of locating more HNPs compared to BHCs. This network is obviously cheaper but average travel distances increases. This is consistent with the computational results from the previous sections. When locating a smaller number of facilities, the distance that a client must travel to avail it increases. The cost of reaching these facilities are then shouldered by the clients.

An important consideration in these modelling approaches was the spatial distribution of the facilities, which directly relates to enhancing the equitable access to health services. There is no significant difference in the configurations generated. There are no distinct advantages to applying one model to the whole city compared to implementing separate models. A significant number of facilities are still being located in the interior of the rural region which is an important consideration when seeking to increase equity. Given this, it would be better to use a single modelling tool for the whole city rather than developing separate tools for different areas of the city.

But the possibility of using separate tools for different regions must not be discarded. By applying separate models, analysts are assured that a fixed number of facilities are located in these areas. It is also important to establish the existence of unique characteristics to these regions that would directly affect the behavior of the model itself. Examples of this include utilization behavior of particular population groups, demand for health services, supply of health services as well as alternative choices. These factors can significantly affect the behavior of the model and, at the same time, is not fully captured when aggregated to the city level. Another important aspect to this
approach is the geographic partitioning method used in the city. In this study, the city was divided into 2 geographic parts: urban and rural. There are different ways in which the city could be partitioned based on such criteria such as identifying areas with high levels of unmet health needs or areas where the population is very vulnerable to certain conditions or diseases.

5 POLICY IMPLICATIONS

Access to health service is a vital component of any health care delivery system. The literature has shown that distance between clients/patients and health facilities is an important factor in utilization behavior. But how access is defined is still very subjective. Determining an “acceptable” distance value, regardless of what model is used, requires subjective assessment. The sensitivity analyses done on the two models reveal that the number of facilities within a hierarchical network as well as its level of coverage is highly dependent on the values of coverage distances used. Longer coverage distances results in a wider coverage area therefore covering a larger proportion of the population. And the reverse is true for shorter coverage distances. Given an “acceptable” coverage distance, the population covered is considered to have access to these facilities.

But the difficulty lies in determining what is the “acceptable” coverage distance. Sensitivity analysis reveals that there is a trade-off between costs shouldered by the health system (the local government) and the patient or client. In a network of fewer facilities, clients or patients have to travel relatively farther to reach these facilities. This creates a greater financial burden for the clients or patients. For policymakers, the question then shifts from accessibility of health facilities to a question of cost-sharing. How much cost is the local government willing to shoulder in order to make health facilities more accessible?

The models used in this analysis have shown that there are substantial financial and social benefits that could be gained from shifting to a hierarchical network of facilities. The total overhead cost of a hierarchical network of facilities is lower compared to the current system. The savings generated could be used to enhance current programs or to hire more medical and dental personnel.

Equity is also enhanced. Optimally locating facilities that offer a certain type of service ensures that the people who need them the most have greater access to them. The health services that people need are bought closer to them.

6 CONCLUSION and NEXT STEPS

The current configuration of health facilities system could be improved. By optimally locating health facilities, the performance of the network is improved even without adding a new facility. Locating a network composed of a smaller number of facilities yield a comparable
performance to the current configuration. The performance of these alternative configurations, in terms of average distance traveled and population coverage, are equal or better than the current system.

But, on the other hand, there are also cost trade-offs. Networks with more facilities costs more to operate but it also shortens the distance that a person needs to travel to access services. This results in a smaller financial and opportunity burden on him/her. On the other hand, networks with fewer facilities are cheaper but creates a financial burden for the client or patients. Clients would have to travel farther to gain access to services which translates to higher out-of-pocket costs and opportunity costs.

6.1 MODEL EXPANSION

• Despite the method used in this study to split the rural barangays, a more systematic procedure that reflects the actual settlement pattern within the rural barangays should be developed. The most ideal would be to show the clustering of residences in the interior of the barangays. This could lead to a more systematic and realistic way of splitting the rural barangays.

• A better metric to estimate and forecast demand for health services at the community level should be developed. At present, the city has access to two community-based datasets – the Community-Based Management Information System (CBMIS) and the Living Standard Index Survey. These datasets could provide inputs to better estimate and forecast demand levels. A helpful reference would be the study conducted by Griffin, et al (2006) in Georgia.

• A more comprehensive street network should be used to accurately capture travel distance, time and costs associated with accessing health services. This is not limited to the national highways, primary and secondary roads. It is important that the all-weather roads and common paths used by residents are also plotted. This is especially important in the rural areas where there are no formal road networks apart from the Bukidnon-Davao highway the traverses this region.

• Since equity is a major factor being considered in improving the health service delivery network, equity measures must be developed and integrated into the prescriptive model. This is to enable analysts and planners to measure and track the “amount of equity” that is present within a particular alternative.

• A gravity-type model could also be developed to model the consumer behavior when it comes to utilizing health services available in these facilities. Coupled with a better demand metric, a more accurate and sophisticated planning model could be developed and used.
Another interesting expansion to the modelling tools used in this paper is the use of the maximal covering network improvement model developed by Murawski and Church. Using a more comprehensive road network map that includes paths and trails leading to the far flung barangays, this model would be helpful in generating a set of alternatives that looks into improving the road infrastructure. By improving parts of the road network, the social benefits gained is not limited to increased accessibility of health services. Farm-to-market roads are improved creating lower transportation costs for farmers. Far flung communities would also have greater access to other social services, not just health care.

7 BIBLIOGRAPHY


Murawski, Lisa and Richard Church. Improving accessibility to rural health services: the maximal covering network improvement model. Draft paper, 2006


