Improving Geographic Accessibility to Community-based Health Facilities in Davao City through Location-Allocation Models

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ABSTRACT

Alternative hierarchical location-allocation models are used to locate two types of community-based health facilities in Davao City relative to population locations. Accounting for factors such as politics and resource availability, different optimization approaches were implemented to locate a mix of health centers and nutrition posts across the rural and urban areas of the city. The results were evaluated based on operating costs, average travel distance and population coverage. Computational results revealed that, by optimally locating barangay health centers and health and nutrition posts, the current level of public investment in the health delivery infrastructure can be sufficient to cover a significant proportion of the population and at the same time, reduce the travel distance to these facilities. Greater cost savings could be generated with a network comprised of fewer facilities since the overall operating costs are reduced. Significant policy insight that can be derived from this study is that public investments are more effective and efficient when community-based health facilities are optimally located.

Key Words: : health facilities, linear programming, location-allocation model, geographic access

Introduction

Developing countries wish to improve their healthcare delivery systems but lack the necessary resources to do so.[1] Local governments must balance conflicting yet equally important issues such as economic development, peace and order and social development initiatives constrained by financial and human resources. For years, health facilities planning, particularly in community-based health centers, has been driven by political expediency and availability of public land. How can a city in a developing country improve the delivery of health services through the organization of its network of community-based health facilities? This study shows that substantial improvements in terms of cost savings for local government and increased accessibility of health services are possible without significant public investments through the use of two simple optimization models when locating hierarchically networked community-based health facilities.

Davao City is a metropolitan city in Southern Philippines covering an area of 24,400 square kilometers (9,420.9 square miles). In 2007, the city's population was pegged at 1,147,116, spread over 180 barangays or villages. Most of the population is still largely concentrated in the city's urban center. Barangays with low population densities, especially in the rural areas, are less attractive to private and public investments on health infrastructure (e.g., hospitals, clinics). This leads to significant disparities in health outcomes because most of the rural population is poor and are more likely to be dependent on publicly provided health care services compared with their urban counterparts.

The hub of outpatient care in community-based delivery of health programs and services is the Barangay Health Center (BHC), which is managed by a licensed midwife and assisted by volunteer Barangay Health Workers. At present, there are 120 BHCs in the city. Most of the BHCs (85%) are in the urban center and the surrounding suburban area, consistent with the city's population distribution. This distribution and the location of BHCs have adverse effects on the rural population's level of access to health facilities and, ultimately, the efficient delivery of healthcare services since health programs and services are more accessible to the urban residents compared with their rural counterparts. In addition to the lack of health facilities, people in the rural areas also face other barriers to access. Located on the mountainous part of the city, the topographical make-up of this region makes traveling from the community to the highway difficult and expensive.

The Health and Nutrition Post (HNP) is another community-based facility run by the city. These facilities serve as staging points for information, education and communication (IEC) activities for the city's nutrition program as well as an extension of the BHCs where programs such as feeding programs, Operation Timbang and growth monitoring are also conducted. In contrast to BHCs, these facilities are managed by volunteer health workers, mothers and a nutrition scholar. Funding is shared by the city and the barangay. At present, the city plans to operate 54 HNPs in the city.

The budgetary allocation of the local government for health has increased by more than 2000% from 1986

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(PhP4.29M) to 2000 (PhP 120.92M). But its proportion to the city's total budget has decreased to 7% in 1997 from a peak of 56% in 1986.[2] According to the City Health Office, a number of health centers have been closed in the past few years due to the lack of financial resources. These trends indicate that the healthcare system cannot expect any significant investments in the future as well. Given limited financial resources, the local health system is faced with the challenge of equitably and effectively delivering health programs and services to all its constituents.

The succeeding section looks into the related literature on spatial accessibility and utilization of health facilities. Section 2 discusses the methodology of the study, including a section on the two model formulations. Section 3 presents computational results for both models as well as the sensitivity analysis. The last section discusses the conclusions, implications and model extensions.

Spatial accessibility and utilization of health facilities

For developing countries, the physical accessibility of health facilities by the target population plays an important role in ensuring that health services offered by these facilities are efficiently and equitably delivered. This is determined by the location of client households in relation to available facilities, by physical and topographical barriers and by the modes of transport that are available to reach these destinations.[3] Over the years, many studies have shown that geographical accessibility of health services strongly influences the utilization of these services.[4,5,6,1,7,8,9,10] Limited physical access to primary healthcare is a major factor contributing to the poor health of populations in developing countries.[11] Once a patient decides to visit a facility, its location and accessibility measures (i.e., travel time, travel cost) as well as other factors such as perceptions of quality of care and timeliness of care, affects choice of facilities available to the patient.

Spatial accessibility is defined as the fusion of two barriers to "realized access" or utilization of services that are spatial in nature: *availability* and *accessibility*. Availability refers to the number of local service points from which a client can choose while physical accessibility is the travel impedance (distance or time) between patient location and service points.[10] 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.[12] 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 is closely associated with two factors: travel time and transportation cost.[9] Studies have amply shown the important role of distance in reducing the use of health facilities, especially in rural areas.[9] Longer distances entail longer travel times as well as higher transportation costs. In a study on the effect of distance on maternal mortality, the physical accessibility of health facilities directly affects the decision to access maternal care (phase 1) and the identification and arrival at the health facility (phase 2). Longer distances are "actual obstacles to reaching a health facility."[7] Combined with roads in poor condition and the lack of transportation, this acts as a disincentive to even try to acquire care.

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 these services. 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, the physical locations and spatial or geographic characteristics of the area where these facilities are located that ultimately determine the utilization levels.

An approach to gaining deeper insight into the intricate relationship between the accessibility of health facilities and the utilization of health services is the use of facility location models. These explore how facilities should be sited, and the sizes, locations and demands served by each facility.[13] It is a mathematical optimization technique that evaluates whether a site should remain open, or whether an existing facility should be closed, or where a new facility should be located based on costs and constraints.[14] Real-world applications include choosing the best locations for bank ATM, ambulance and fire stations.

Proximity is one of the fundamental aspects of location analysis.[15] It assumes that clients are more likely to go to facilities closest to them. But this assumption has been found to be insufficient in modeling the patients' utilization behavior. Hodgson (1988)[6], posts that other than distance, facility attractiveness, facility size, quality of service, waiting time and perceptions of quality of care are also important factors in a client/patient's decision to patronize a facility. In the model he proposed for a primary healthcare delivery system, he integrated both a distance decay coefficient (β) as well as an "attractiveness" coefficient (α). Although these are intuitive and logical, it also requires extensive empirical investigation in order to capture its true values. Its limitations include the nature of the illness, the quality of care and social and wealth status, and the relationship of the patient to the physician in the health facility (social distance).[9]

There are instances where facilities to be located are of different types and offer interrelated or "linked" services. In a healthcare system, clinics, local hospitals and regional hospitals offer services in these facilities either overlap (e.g., primary care services) or are unique to a particular facility (e.g., complicated inpatient services). Hierarchical service systems also exist in distribution networks, community extension programs, and in many other public facility and service systems.[16] Models that deal with a hierarchical network of facilities are considered a subset of location models. A unique feature of the hierarchical location-allocation models is that these *simultaneously* locate different types of facilities. The benefits to the public healthcare system would be greater since the similarities and differences in the types of services offered are taken into consideration when locating health facilities. There is an extensive collection of work on hierarchical location-allocation models including the seminal works of Moore and Revelle (1982)[16] and subsequent works by Hodgson (1986, 1988) [5,6], Eitan, et al. (1991)[17], Oppong and Hodgson (1994)[1], Daskin (1995)[13], and Boffey, et al. (2003)[18].

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). The research in this area is sparse. A recent study by Griffin, et al. (2006)[19] presented a process for estimating healthcare need within individual geographical areas from publicly available data. Using the survey component of the 1999-2002 US 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 were then used to estimate the health demand levels. In developing countries, estimating and forecasting demand for health services is a challenge since the availability of a sophisticated dataset similar to the one used in this study is highly unlikely. But this should not impede the use of such models in resource-poor countries. It is, therefore, imperative to identify proxy or alternative datasets that would closely approximate demand for health services at the individual and community levels.

Methods

Two hierarchical location-allocation models were implemented to gather insights into the optimal configuration of a network of community-based health facilities. These models are the Hierarchical Coverage Model (HCM) and Hierarchical Median Model (HMM). Model formulations used were based on those presented by Daskin (1995). These optimization models were used to locate facilities in the rural and urban areas separately and in the city as a whole. These were implemented in MS Excel 2003 and 2007. The optimization model was run using trial versions of the Premium Solver add-in for MS Excel (versions 6.0, 7.0 and 8.0).

HCM maximizes the total population that is within fixed distance or travel time of a 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 coverage distance and the number of facilities to locate are binding constraints that limit the proportion of the population that is "covered". The performance metric used is population coverage or the proportion of the total population that is within the specified coverage distance.

On the other hand, HMM minimizes the total demand-weighted distance from the demand nodes to the facility sites. This is achieved by assigning demand sites to specific facilities in order to minimize the overall demand-weighted travel distance for the network. For this model, the only binding constraint is the number of each type of facility to be located. The performance metric used for this model is the average travel distance (ATD), which is the distance that each person in the network travels on the average to reach their "assigned facility" to access a particular type of service which is available in either HNP or BHC. This was computed by dividing the demand-weighted travel distance for each type of facility by the total population eligible for the services being offered in each facility.

The hierarchy of facilities envisioned for this study is a two-tiered system composed of Health and Nutrition Posts (type 1 facility) and Barangay Health Centers (type 2 facility). HNPs offer a limited menu of health services that specifically targets children aged 0 to 5 and women of reproductive age (type 1 service) while the BHCs offer a complete menu of health services (type 2 service) including those services offered in the HNPs.

The health system configuration under consideration in this study is a ***globally inclusive service hierarchy with a successively inclusive facility hierarchy***. There is no geographic constraint as to who can utilize the services of a particular health facility. At the same time, there is an overlap in the services offered between the HNP (lower-level facility) and the BHC (higher-level facility).

The demand metric used for both models was the total barangay population count from the 2000 Census (CHO, 2000). The estimated demand for BHC services is the total barangay population while the estimated demand for HNP services is only a fraction of the barangay population. These estimates are based on standards set by the City Health Office.[1]

The distance measured used was the straight line (Euclidian) distance between the geographic centers (centroids) of the barangay. Centroids were generated using the built-in VB Script in ArcGIS. A distance matrix was then generated using another VB Script[2] to produce the centroid-to-centroid Euclidian distances.

Assumptions were made to generate these models. It was assumed that there are no facilities currently on the ground ("green field"). Instead, the analysis focused on the comparability of locating the current number of facilities with other mixes of BHCs and HNPs. The population was assumed to be concentrated at the geographic center of the barangay. This then made it logical to locate the health facility at the centroid. The annual overhead costs for a BHC was assumed to be PhP 1,000,000, which is based on the expenditure schedule for the Ma-a BHC, assumed to be representative of most BHCs. On the other hand, the overhead cost for HNPs is assumed to be about half of the

[1] 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). These factors were then used to determine the demand level for HNP services.

[2] VB Script developed by Li Zou. Available at http://arcscripts.esri.com/details.asp?dbid=13957

annual overhead costs of a BHC since it is a smaller facility and run by volunteer staff. Lastly, barangay population was used to estimate demand for health services. A more sophisticated measurement of demand would require administrative data that is currently unavailable.

Using HCM and HMM, different ways of optimally locating BHCs and HNPs across the rural and urban regions of the city were explored. The city was first split into rural (27) and urban (153) barangays because the topography and population distribution are systematically different for both areas. For the rural region, a base case analysis was done to illustrate changes in model outcomes that might be lost due to wide geographic space in the rural region and the uneven population distribution within this region. Both HCM and HMM were implemented using the existing geographical boundaries of rural barangays ("unsplit barangays") as well as a hypothetical situation where the rural barangays were split into smaller geographic units ("split barangays").

To split the barangays into smaller geographic areas and estimate the settlement patterns, a number of assumptions were made. It was assumed that health facilities are located where the settlements are. 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 by creating buffer zones around these infrastructures. There were 21 "new" barangays generated. Assuming that 70% of the population lives in areas near the road or a BHC, population was then redistributed across the newly created barangays.

Two sets of sensitivity analyses were also done using the two models to compare the base case (current number of facilities on the ground) to 10 alternative network configurations for the rural and urban barangays. The number of one type of facility was adjusted while holding the number of the other facility constant and vice versa. This was to show the changes in the performance metrics when different network configurations were used in the models.

Results

Rural Barangays: Base Case Analysis

For the base case scenario, the current number of BHCs (18) and HNPs (0) 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, based on the assumed operating costs per BHC.

In terms of coverage, there is no significant difference in the proportion of the population that is covered (100% coverage). On the other hand, computational results show that clients travelled an average of 0.97 kilometers to reach a BHC.

Compared to the actual locations of BHCs in rural barangays, the location of BHCs generated in this scenario is considered optimal, whether split or unsplit barangay boundaries are used. More facilities are located in more isolated parts of the rural areas. This highlights the inequities that result from the actual location of facilities. The lack of road networks as well as the distances between settlements and health facilities makes accessing the services more difficult, especially for those who live in far-flung, isolated parts of the barangay.

Rural Barangays: Sensitivity analysis of alternative mix of BHCs and HNPs

Using the split barangay boundaries, HMM and HCM were implemented using different combinations of the number of HNPs and BHCs to be located. The computational results are shown in Table 1.

Since "split" barangay boundaries and redistributed population figures were used, it is expected that the coverage of BHCs would be higher than 70%. But with the addition of HNPs to the mix of facilities, the overall population coverage is enhanced. Across the 10 scenarios, BHC coverage ranges from 74% to 99%. The percentage coverage of HNP is understandably lower because the rural barangays are far from each other and there are only a limited number of barangays that would fall within its coverage distance (2 kilometers). But, despite this, there is a greater chance for those living near an HNP to access available services.

Across the 10 scenarios, the average distance the clients travel to access type 1 services which are available in HNPs and BHCs ranges from 0.22 to 1.34 kilometers. This can be directly influenced by the number of HNPs being located. The same pattern can be seen for BHCs where clients travel from 0.91 to 3.76 kilometers on the average to access type 2 services which are available only in BHCs. This is rather intuitive since accessibility is constrained by the number of facilities that offer the services needed. Clients will have to travel longer distance when there is a limited number of facilities that offer the services they need.

Two interesting trends can be seen in the sensitivity of the distance travelled by clients to avail of type-1 services which are available in both types of facilities to changes in the number BHCs to be located. Scenarios 6 to 10 offer a mix of facilities where the number of HNPs was increasing, holding the number of BHCs constant at a relatively low number (9 facilities). This resulted in shorter travel distance to avail of type 1 services. This pattern indicates that HNPs compliment the functions of BHCs by making a limited menu of services that are considered more urgent at the community level more physically accessible. So even if there is a limited number of BHCs, HNPs plays a significant role in bringing more vital services closer to the community.

On the other hand, the first five scenarios were scenarios in which the number of BHCs was decreased while holding the number of HNPs constant. The average travel distance to type 1 and type 2 services increased as the number of BHCs decreased. This indicates that the network can be adversely affected when there are less BHCs. BHCs are staging points for all community-based health programs (type 2) including

Table 1. Computational results for rural barangays of Davao City using HCM* and HMM**

		System cost		Covered Population (%)		Average Travel Distance	
# of HNP	# of BHC	Total Cost (PhP)	Cost per capita (PhP)	HNP	BHC	HNP	BHC
0	18	18,000,000.00	207.48	0 (0%)	85,482 (99%)	0.91	0.91
15	18	25,500,000.00	293.93	4,185 (74%)	85,482 (99%)	0.26	0.91
15	15	22,500,000.00	259.35	4,185 (74%)	84,405 (97%)	0.34	1.17
15	12	19,500,000.00	224.77	4,185 (74%)	81,603 (94%)	0.44	1.65
15	9	16,500,000.00	190.19	4,185 (74%)	76,165 (88%)	0.58	2.47
15	6	13,500,000.00	155.61	4,185 (74%)	64,164 (74%)	0.72	3.76
5	9	11,500,000.00	132.56	2,677 (47%)	76,165 (88%)	1.34	2.47
10	9	14,000,000.00	161.37	3,600 (64%)	76,165 (88%)	0.87	2.47
15	9	16,500,000.00	190.19	4,185 (74%)	76,165 (88%)	0.58	2.47
20	9	19,000,000.00	219.01	4,600 (82%)	76,165 (88%)	0.36	2.47
25	9	21,500,000.00	247.82	4,931 (87%)	76,165 (88%)	0.22	2.47

*HCM - Hierarchical Coverage Model
**HMM - Hierarchical Median Model

Table 2. Computational results for urban barangays of Davao City using HCM* and HMM**

			System cost		Covered Population (%)		Average Travel Distance	
	# OF HNP	# OF BHC	Total Cost (PHP)	Cost per capita (PHP)	HNP	BHC	HNP	BHC
BASECASE	0	102	102,000,000.00	95.41	0 (0%)	1,069,110 (100%)	0.18	0.13
SCENARIO 1	35	102	119,500,000.00	111.78	61,585 (89%)	1,069,110 (100%)	0.01	0.13
SCENARIO 2	35	80	97,500,000.00	91.2	61,585 (89%)	1,069,110 (100%)	0.05	0.23
SCENARIO 3	35	60	77,500,000.00	72.49	61,585 (89%)	1,069,110 (100%)	0.13	0.39
SCENARIO 4	35	40	57,500,000.00	53.78	61,585 (89%)	1,069,110 (100%)	0.26	0.66
SCENARIO 5	35	20	37,500,000.00	35.08	61,585 (89%)	1,069,110 (100%)	0.45	1.36
SCENARIO 6	5	50	52,500,000.00	49.11	31,149 (45%)	1,069,110 (100%)	0.66	0.51
SCENARIO 7	10	50	55,000,000.00	51.44	42,472 (61%)	1,069,110 (100%)	0.50	0.50
SCENARIO 8	15	50	57,500,000.00	53.78	49,880 (72%)	1,069,110 (100%)	0.39	0.50
SCENARIO 9	20	50	60,000,000.00	56.12	54,956 (79%)	1,069,110 (100%)	0.33	0.50
SCENARIO 10	25	50	62,500,000.00	58.46	58,127 (84%)	1,069,110 (100%)	0.28	0.50

*HCM - Hierarchical Coverage Model
**HMM - Hierarchical Median Model

type 1 services. When the number of BHCs contract, access to these services then becomes more difficult since there are less facilities available, even if there are HNPs.

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 must be weighed against the cost that it takes to achieve it. The smallest configuration (Scenario 6) entails an operational cost of Php 11,500,000.00 or PhP 132.56 per capita. But they would have to travel a longer distance (2.55 kilometers) to avail of the services which translates to higher transportation costs, loss of income as well as more time to acquire treatment. In contrast, the largest number of facilities to be located (Scenario 2) entails a public investment close to PhP 300.00 per person, but clients would travel less than 1 kilometer to avail of health services. Either scenario shows that there is a trade-off between public investment costs and making health services more accessible by bringing it closer to the population.

Urban barangays: Sensitivity analysis of alternative mix of BHCs and HNPs

There are 157 barangays in the urban region. These are the barangays located in the downtown area and the surrounding suburbs. The computational results for HCM and HMM implementation are in Table 2.

At present, there are 102 BHCs in this part of the city, which serves as the base case for this analysis. Computational results for this scenario indicate that 100% of the target population for BHC services is covered while a smaller proportion of the target population (89%) for HNP services is covered. A client travels from 0.13 kilometers to avail of type 2 services in the BHCs and 0.18 to avail of type 1 services which are available in HNPs and BHCs. This shows that the number of facilities on the ground is sufficient to serve the city's urban population. Given the short distances between facilities, clients can easily avail of BHC services in other barangays as well.

This pattern can also be seen across the 10 scenarios used for sensitivity analysis. A client travels 0.01 to 0.66 kilometers to avail of type 1 services which are available in

HNPs and BHCs and 0.13 to 1.36 kilometers to avail of type 2 in the BHCs. These short average travel distances could be attributed to the short distances between barangays in the urban region.

Sensitivity analysis reveals that changes in population coverage and average travel distance is not significantly different from the base case. Scenario 1 to 5 are configurations where the number of BHC facilities are incrementally decreased by 20 facilities while the number of HNP facilities to be located is held constant (35 facilities), which is also the number of HNP facilities that the city is planning to locate. Computational results show that there is no change in the number of covered population (100%). The change average travel distance is also not significant. Clients in the urban setting will still be travelling less than 1 kilometer to avail of a particular type of service in the facility they are assigned to. On the other hand, Scenarios 6 to 10 are configurations where the number of BHCs are halved and held constant while the number of HNPs are incrementally increased five. Although the proportion of population covered by HNP services is increasing, the marginal increase in the percentage of population covered by HNP services declines as more facilities are added due to the overlap of functions between the HNP and BHC as well as the lower number of HNPs being located. The changes in travel distance are also very minimal although they are slightly higher compared to the results of the first five scenarios.

But across the 10 scenarios, the cost savings generated is fairly significant especially when locating a smaller network of facilities. Scenario 1 has the most number of facilities combined. It entails a total public investment reaching PhP120,000,000.00 or PhP 111.78 per capita. Under this scenario, clients will travel a shorter distance on the average (0.13 kilometers). On the other hand, Scenario 5 has the smallest configuration but only costs one-third of the Scenario 1. This translates to an investment of PhP 35.08 per capita. The level of coverage is the same while the average travel distance increased to 1.38 kilometers

Discussion

The HCM and HMM are tools that determine the optimal location of a given mix of facilities that have a hierarchical relationship. This is particularly valuable in a resource poor setting where it is impossible to put up community-based facilities in every community and where there is a greater imperative to avoid duplication of services. These models provide insights on the performance of a mix of facilities based on population coverage and average distance that clients will travel to access health services.

Assuming no capacity constraints, the current number of BHCs is likely to be sufficient to meet the current demand level for health care. But the challenge 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 incapable of fully accessing these health services. By optimally locating health facilities, computational results indicate that the current system can be improved, even without adding a new facility. This can be seen in the 100% coverage achieved when the current number of health facilities (base case) was located using HCM and HMM. The travel distance that patients must travel to avail of basic health services is shorter than 1 kilometer and the population coverage is 100%.

Sensitivity analysis also shows that locating a smaller number of BHCs and HNPs generates significant cost-savings on the part of the local government without sacrificing performance. The performance of these alternative configurations, in terms of average distance traveled and population coverage, are equal to the base case scenario.

However, there are cost trade-offs. Networks with more facilities cost more to operate but also shorten the distance that clients need to travel to access services. This results in a smaller financial and opportunity burden on the client/patient. On the other hand, networks with fewer facilities are cheaper to operate but place greater financial burdens on the clients/patients in terms of transportation costs, time and loss in income.

Ultimately, the number of facilities as well as their geographic locations influence the distribution of costs between the local government and the clients themselves. The focus then shifts to the local government's willingness to invest to achieve a desirable level of accessibility and equity in the rural areas of Davao City.

Conclusions

This study shows that it is possible to have a smaller mix of of community-based health facilities on the ground by ensuring that these facilities are optimally located such that the population covered is maximized and the distance to be travelled in order to access health servcies in these facilities is minimized. This generates significant cost-savings on the part of the local government without sacrificing performance. But there are also trade-offs on the part of clients and patients.

Policy implications

An important policy insight that can be derived from this study is that local governments can do with lesser health facilities on the ground. By ensuring that these facilities are optimally located, public investments in these facilities are more effective and efficient. The model presents a more efficient application of public investments on health facilities.

There is also a need to integrate the hierarchical nature of health facilities when planning and operating health facilities. Whether one looks at community-based health centers or hospitals, these health facilities are essentially a part of a network of interdependent institutions linked by the services that they provide. The current state of location planning in the country looks at a health facility (e.g., barangay health center or primary hospital) as an institution that is located in relation to similar institutions rather than viewing it as part of a network of interdepedent facilties leading to duplication of services as well as an imbalance in the types of facilities and the specific services each type of facility presents in a health service delivery system. By considering the hierarchical nature of a network of health facilities, planning and implementing inter-facility referral systems are greatly enhanced. Unnecessary duplication is avoided because higher-level facilities can choose to provide an add-on service over and above those offered in lower-level facilties or provide a totally different package of health services.

Model Expansion

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.

To improve the computations done in using HCM and HMM, there is a need to come up with (1) better measures to estimate demand, (2) an accurate street network map of Davao City and (3) locating demand.

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