HEALTH CARE FACILITIES LOCATION MODEL WITH GENETIC ALGORITHM

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Abstract: This study aims at developing the formulation and the solution procedure for allocating hierarchical health care facilities. The health care facilities (HCF) from each of several types serving a given region offers an efficient indicator of hierarchy. This is related to the patients weighted distance and the difficulties of producing services. In this study, hospital and health centers play an important role of HCF activity. We adopt Genetic Algorithm (GA) from the viewpoint of computational applicability to large-scale problems. The model developed here is applied to Halmahera Islands, Indonesia, where HCF is optimally allocated into several nodes in a network connecting 35 nodes. The application gives the feature of the model and the performance of GA in searching the minimum value of the objective function defined by patients weighted distance. It will affect the precision of locating the state of these facilities in node.

1. INTRODUCTION

The costly and inefficient producing of completely services for health cares in all demand nodes motivate us to study the facility location as a hierarchy. The several different levels of services and patients capacity have identified the hierarchical health care facilities. The key issue in health care facility that we are concerned with are: (1) how to allocate demand nodes with a set of facility type, (2) where they should be located, and (3) how the patients should flow through the system. This problem is particularly complicated in a demand network, which contains the spreading of villages on small islands and big islands like the case of Halmahera Islands, Indonesia.

To attack this problem, Daskin (1995) suggests a model to minimize the total demand (patient) weighted distance between a demand node and the nearest health care facility based on the median problem. The facility types contain hospital and health center or local clinic. The median model has a power in linking the location variables and the allocation variables. Based on Daskin's framework, we develop a model with the following additions:
(1) the constraints on capacity of facility,
(2) the distance between health center and the hospital are guaranteed within a given critical coverage distance, and
(3) the minimizing referral weighted distance from the health centers to the hospital with its linking constraints. The location variables and the allocation variables use 0-1 variables.

The hierarchical health care location problems are essentially NP-Complete. For solving such a network like Halmahera Islands, it needs a heuristic approach. The heuristic approach is basically concerned with an applicability and effective computer time. Motivated by Genetic Algorithm (GA), we intend to solve hierarchical health care facilities model. The choice of facility site is randomly determined in GA approach. To deal with the nature of the model, we conditioned the GA variables and the GA operations. Basically, GA has a duty to produce a number of candidate sites, that is, producing a number of locus for filling 0-1 variables. A 1 and a 0 denote located facility and unlocated facility. Since, there are hospital and health center location variables and they are simultaneously worked in the related network based on their definitions in the model. We create a pair of string for placing hospital and health center candidate site, respectively. Each pair of string contains solution variables of the problems. The operators of GA have an addition duty for keeping the number of each facility and the unoverlapping locations. We applied the location model of health care facilities to Halmahera Islands, Indonesia, where 35 demand nodes in a network mainly consisting of sea transportation links are optimally allocated.

This paper falls into six sections. In section 2, it offers the key concept to an understanding the background of hierarchical health care facility location including the notion of coverage distance. Section 3 deals with the assumptions, notations, and the formulation of the model. Section 4 contains the computation algorithm where the coding and its GA operations are declared step by step. Application to Halmahera Islands will be demonstrated in section 5.

2. BASIC NOTIONS

2.1 Systems of Hierarchical Facilities

Often, facilities are hierarchical in terms of the type of services being offered. Stephen (1977, in the IEEE Transactions on System, Man, and Cybernetics, Vol. 21, No. 1 of Eitan *et al*, 1991) identifies three levels of facilities:
1) primary facilities which includes health center and village clinics that offer first aid and preventive services,
2) secondary facilities which includes general hospitals that offer specialized and curative services, and
3) tertiary facilities, which include medical centers that offer superspecialty services such as, heart surgery.

This hierarchy is depicted in figure 1. Typically, in this framework, the secondary facilities include services provided by the primary facilities, while the tertiary facilities provide only services unique to itself. Interestingly, Ruth (1981) uses the same three classifications to group hospitals in a ***successively inclusively*** manner.

Based on location of health care facilities in developing countries, health center or local clinics may provide basic care as well as diagnostic services. Community hospitals will provide basic care and diagnostic services as well as outpatient surgery and limited in-patient services. Regional hospitals may perform outpatient surgery, in-patient surgery, and provide a full range of in-patient services. However, regional hospitals may or may not provide basic care and diagnostic services. Thus, hierarchical system similar to the one shown in figure 1 is applied.

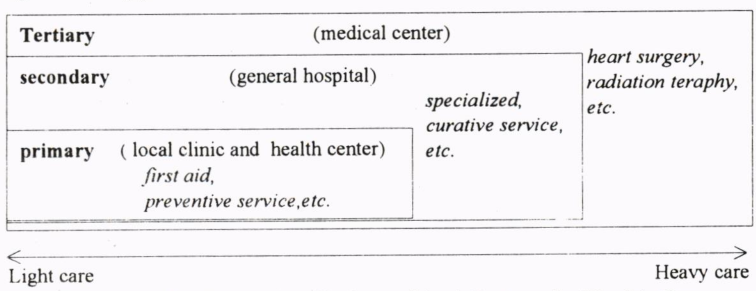


Figure 1. An Example of Hierarchical System in Health Care

As indicated by the facts above, in hierarchical facility location problems, facilities at different levels of the hierarchy are distinguished by the services they provide. In addition, there must be some sort of link between the facilities being located. The number of facility at each hierarchy is usually treated as explicit constraints. However, Moore and ReVelle (1982) suggests an alternative approach, where the link between the facilities is an implicit link that limits the amount of money that can be spent on all of the facilities. Thus, the problem becomes one of (1) allocating the budget between the different hierarchies, (2) locating facilities at each hierarchy, and (3) allocating customers to facilities (Daskin, 1995). In other cases, the link between facilities at different levels of the hierarchy may be more explicit. Daskin (1995) also describes that in a health care context, there may be linkages that identify which local clinics can refer patients to which community hospitals.

Hodgson (1986) suggests that going from single to multi-level facility systems involve two major complications. The first is that, given successive inclusiveness, locational decisions at each level are affected by those at other levels. Early attempts at hierarchy location adopted a simple one-way dependence strategy under which the location of facilities at each level is highly dependent on the location patterns of previously located levels and completely independent of the needs of successively located levels. A second difficulty has to do with the relationship between patron behavior and facility level.

Generally, health service facilities with the large coverage are the health centers or the village clinics and the hospitals. It generally means as follows. Firstly, health center is headquartering of a group of local medical services. In developing countries, health center is a functional health organizational unit, which serves as a health development center, which not only renders conventional health services to the community in its area of responsibility, but also plays an important role in promoting community participation in health activities. Commonly all patients for the first time will be examined by a physician at a health center (with widely meaning; a hospital also contains a health center) before receiving treatment at hospital. Thus, all diagnostic and referral services are located at the health centers. In essence, the health centers act as gatekeepers for the hospitals. Secondly, hospital (or general hospital) is an institution that provides medical and surgical treatments and nursing care for ill or injured people.

Much type of facility hierarchies will be described as follows:

(1) A ***successively inclusive facility hierarchy*** is one in which a facility at level m (the highest level) offers services 1 through m (see figure 2(a)).
(2) **A *successively exclusive facility hierarchy*** is one in which a facility at level k offers only service type k. in other words, a successively exclusive for a successively inclusive facility hierarchy is one in which the set of services offered by a type k facility has no intersection with the set of services offered by a type n facility as illustrated in figure 2(b) (Daskin, 1995).
(3) A ***globally inclusive service hierarchy*** is one in which a type k facility at location i offers service of types 1 through k to customers at all nodes (see figure 2 (c)).
(4) For a successively inclusive facility hierarchy, a ***locally inclusive service hierarchy*** is one in which a type k facility at location i offers service of types 1 through k to demands at node i, but service of type k only to demands at nodes j $\neq$ i (see figure 2(d)).

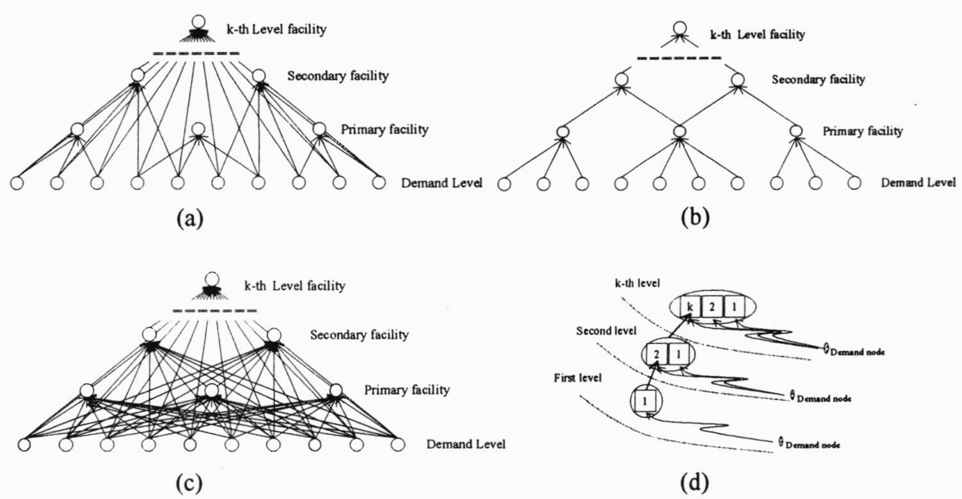


Figure 2. Several Types of Facility Hierarchy

Focussing on modeling, we deal with facility hierarchy type c as illustrated in figure 2 with only two types of facilities. The choice type of the facility is based on the fact that the hospital services contain the health center services and these two facilities are provided for patients at all nodes.

2.2 Notion of Distance

Reducing average distance or travel time to a site of health care facilities contains an equivalent meaning as maximizing services to an existing population. Degree of effort in traveling is strongly related to health conditions of patients. Distance will influence on the motivation of individual to contact with a physician. The grade of illness and death risk are positively related to the distance between the patient and the physician. Thus, it can be hypothesized that the longer the distance from a health care facility, the more risk the patient will get. Girth (1973) evaluates that the decision to seek medical care is thus a result of "transaction between individuals and situations, rather than of either one in isolation," this stress having reached a level sufficient to invoke interaction between the individual and his physician. Gore (1991) describes that it would involve specifying rules of access regarding eligibility, priority, and location of the service and relating those to the person's actual position in the system, including endowment, location, and a wide range of other phenomena relevant to access.

2.3 Notion of Coverage Distance

In many location contexts, service to customers depends on the distance between the customer and the facility to which the customer is assigned. Customers are generally, though not to be always, assigned to the nearest facility. Two important observations should be stated at the outset. First, the possibilities of death or low quality of remaining life and the difficult in measuring quality and value of outcomes. Second the planning of health care access as a right of citizens in society.

Storbeck (1982) has suggested that such siting strategies are inherently behavioral, in that locational configurations are determined in relation to the consequences of siting decisions, rather than to the siting decisions themselves. The consequence, to which we refer, in this case, is the ability to cover demand locations. Thus, we are concerned not with facility placement disperse, but with the resulting coverage patterns of those placements.

Such a behavioral perspective leads us to a clear delineation of locational goals within a given coverage distance. In this case, it is pointed out the distance between two different facilities in term of hierarchy. Since the most basic constraint of related models is to provide "cover" for demand populations by all services, it is natural that locational goals should be framed in terms of coverage. Figure 3 shows the example of health centers that are covered or uncovered by a hospital.

Critical coverage distance is strongly related to the kind of facility to be located. In health care system, since the most important thing is to save patients as quickly as possible, critical coverage distance has sense of critical travel time for referral movements to the next treatment in a higher facility. As indicated above, long travel time can cost live!

To illustrate this point, Daskin (1995) evaluates a commonly cited statistic that if a person's brain is denied oxygen for more than 4 minutes (as a result of a stroke or heart attack, for example), the likelihood of the individual surviving to lead a normal life drops below 50 percent. As a result, the coverage distance should be determined so that the maximum response time is well under 4 minutes.

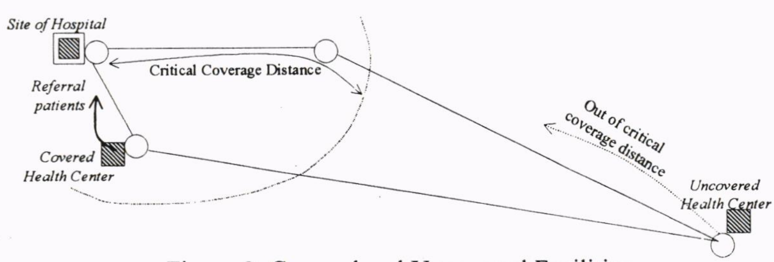


Figure 3. Covered and Uncovered Facilities

3. FORMULATION

A hierarchical health cares facilities system may consist of health centers, hospitals, and medical centers. Such facility systems are generally successively inclusive. That is, in such a system, health centers provide primary care; hospitals provide primary care and some additional services; medical centers provide specialized care in addition to services available at a hospital and a health center. However, Daskin (1995) suggests a simple model to minimize the total patient (demand) weighted distance between a village and the nearest health care facility based on median problem may be described as follows; suppose we want to locate H hospitals and C health centers in any area. Area should be viewed strictly as a plain or a set of many small islands.

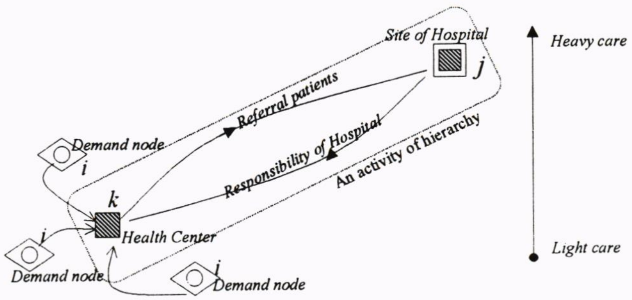


Figure 4. The Activity of Hierarchy

The following assumptions have been made in order to achieve a tractable problem structure. (1) We consider that a health care facility system consists of hierarchically coordinated two level facilities capable of exchanging patients, personnel, equipment and services as illustrated in figure 4. (2) The facilities are located on some demand nodes in bounded plain and or many small islands, and an infinite set of potential facility locations is considered. (3) Users' behavior is based on nearest facility rule as classified in Leonardi (1981). We implicitly dealt with the case in which there was only one type of demand. Thus, we assume that the patients are allocated to the nearest health care facilities. (4) Capacity of a hospital and a health center are given by parameter α and β, respectively. It is related to the total patients for medical treatment in a day. (5) In health care system, the most important thing is to save patients as quickly as possible. Thus, each health center must be located within a unit critical coverage distance of the hospital. (6) It is use zero-one variables to model whether or not a discrete location is executed. Mathematical formulation and notations are written as follows:

H = *maximum number of hospitals to be located*;

C = *maximum number of health centers to be located*;

d_{ij} = *minimum total travel distance between node i and candidate site of hospital j*;

d_{ik} = *minimum total travel distance between node i and candidate site of health center k*;

l_{kj} = *minimum total travel distance between candidate hospital j and candidate site of health center k*;

h_i = *total patients approximately in node i*;

θ = *rate of referral patients*;

α = *given capacity of a hospital (for example: 50 persons per hospital per day)*;

β = *given capacity of a health center (for example: 20 persons per health center per day)*;

Input Variable

$$a_{kj} = \begin{cases} 1: & \text{if candidate health center } k \text{ is within } D_{hc} \text{ distance unit site of candidate site hospital } j \\ 0: & \text{if not} \end{cases}$$

Decision Variables

$$X_j = \begin{cases} 1: & \text{if candidate site hospital } j \text{ is selected} \\ 0: & \text{if not} \end{cases} \qquad Y_k = \begin{cases} 1: & \text{if candidate site health center } k \text{ is selected} \\ 0: & \text{if not} \end{cases}$$

$$W_{ij} = \begin{cases} 1: & \text{if patients at node } i \text{ go to a hospital at candidate site } j \\ 0: & \text{if not} \end{cases}$$

$$V_{ij} = \begin{cases} 1: & \text{if patients at node } i \text{ go to a health center at candidate site } k \\ 0: & \text{if not} \end{cases}$$

$$U_{kj} = \begin{cases} 1: & \text{if referral patients at health center site } k \text{ go to a hospital at candidate site } j \\ 0: & \text{if not} \end{cases}$$

$$Minimize \quad \sum_i \sum_k h_i d_{ik} V_{ik} + \sum_i \sum_j h_i d_{ij} W_{ij} + \sum_j \sum_k \sum_i \theta h_i l_{kj} U_{kj} V_{ik} \qquad (1)$$

Subject To

$$\sum_j X_j \le H \qquad (2)$$

$$\sum_k Y_k \le C \qquad (3)$$

$$\alpha H + \beta C = \sum_i h_i \qquad (4)$$

$$\sum_j W_{ij} + \sum_k V_{ik} = 1 \qquad \forall i \qquad (5)$$

$$l_{kj} a_{kj} \le D_{hc} \qquad \forall k, j \qquad (6)$$

$$Y_k \le \sum_j a_{kj} X_j \qquad \forall k \qquad (7)$$

$$W_{ij} - X_j \le 0 \qquad \forall i, j \qquad (8)$$

$$V_{ik} - Y_k \le 0 \qquad \forall i, k \qquad (9)$$

$$2U_{kj} - Y_k - X_j \le 0 \qquad \forall j, k \qquad (10)$$

$$X_j, Y_k = 0{,}1 \qquad \forall j, k \qquad (11)$$

$$W_{ij}, V_{ik}, U_{kj} = 0{,}1 \qquad \forall i, j, k \qquad (12)$$

The objective function (1) minimize the total patient (demand) weighted distance from a demand node to the nearest health center or hospital and referral patients from health center to hospital. A constraint (2) stipulates that the hospital must be located no more than H hospitals. A constraint (3) states that no more than C health centers are to be located. A constraint (4) states the capacity of hospitals and health centers. Constraints (5) require each node i to be assigned to exactly one facility either health center or hospital. The equation (5) is derived from the users' behavior in choosing facilities as mentioned above. The main point in constraints (5) is that the patient may choose the nearest facilities because (a) the frequency of treatments and (b) the difficult access to another facility as illustrated in a case like Halmahera network. Constraints (6) state the guarantee of critical coverage distance for the distance between the health center and the hospital. Constraints (7) state that at candidate health center k can be covered by more than one selected hospital. Constraints (8) state demand at node i can only be assigned to a hospital at candidate site j if we locate a hospital at candidate site j. Constraints (9) similar to constraints (8) state demand at node i can only be assigned to a health center at candidate site k if we locate a health center at candidate site k. Constraint (8) and (9) link the location variables and the allocation variables. Constraints (10) state the link of referral patients from a health center at candidate site k to a hospital at candidate site j. Constraints (11) and (12) are the integrality constraints, respectively.

4. GA APPROACH

Location problems are always formulated as a combinatorial or NP- Complete problem. We are interested in locating a variety of facilities in a number of possible ways (combinations). Motivated by genetic algorithm, we intend to solve hierarchical health care facilities. GA is an effective way for solving such problem because of the following reasons:
(1) location problems are essentially NP-Complete,
(2) the decision variables could be described as zero—one variables,
(3) the problem could be coded in a form of strings,
(4) the operator of genetic algorithm could be kept in the definition of string.

Actually, our meaning of calculation is pointed out by the GA operations. The procedures are commonly shown in figure 5.

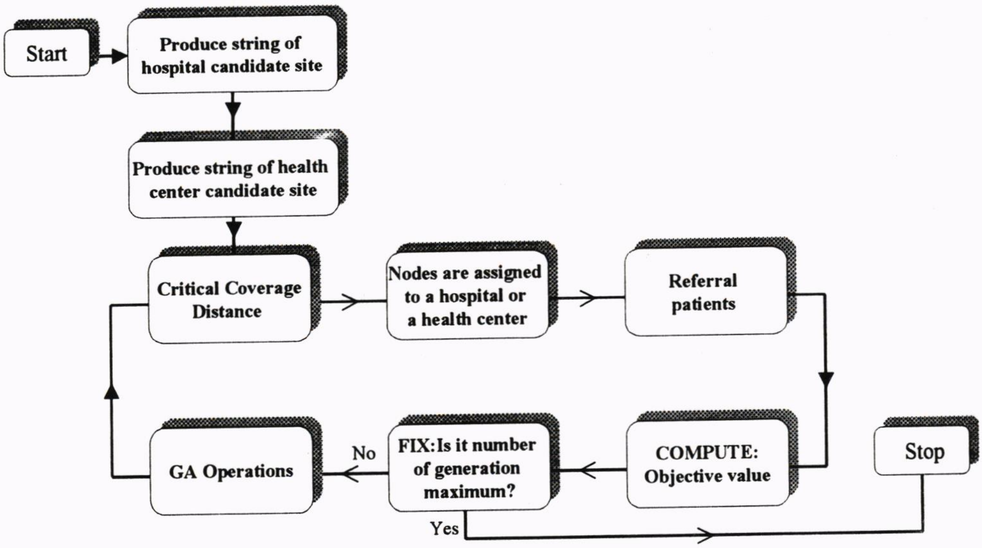


Figure 5. Procedure of GA Approach

The choice of facility site is randomly determined in GA approach. We keep it based on all constraints in a long iteration. Basically, GA has a duty to produce a number of candidate sites, that is, producing a number of locus for filling location variables 0-1. The one set of locus is calling a string. Because there are two types of location variables and they work simultaneously. Thus, based on their definition, these two strings interact in an individual. Furthermore, the individuals will be placed in a population, which is a set of iteration or a generation.

The first string states the candidate site of hospital and the second string states the candidate site of health center. Health center will be located if there is at least one hospital within a critical coverage distance. Then all demand nodes are assigned to one of the health care facility under minimum path. Some of computation processes are shown in figure 6.

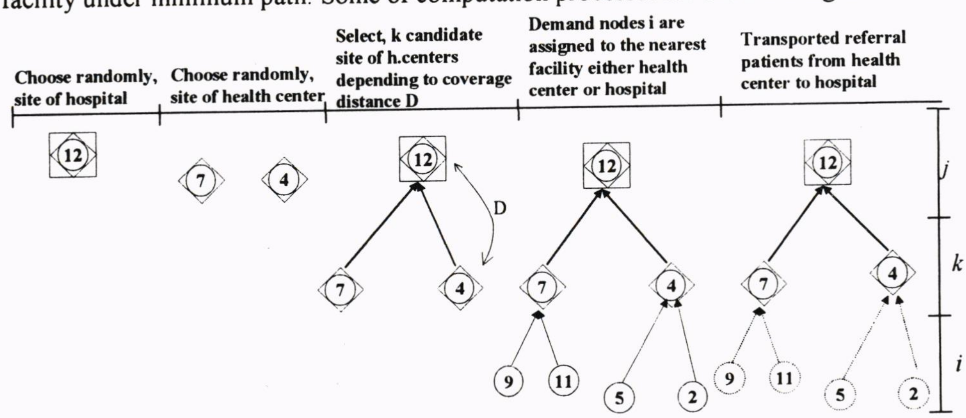


Figure 6. Hierarchy of Hospital, Health Centers and Demand Nodes

String for hospital candidate site is established based on the formulated model. The maximum number of hospital will be transfer in total number of "1" in the strings. Consider, for example, two hospitals to be located. To do this, we keep randomize of zero-one in each string have "1" is only two. In locating hospitals, we may want to balance between the demand and capacity of a hospital. The capacity of hospital is provided by services available for the total patients in a day including the number of available beds. The capacity simply in formulation can be transferred in the sense of string as the given number of hospitals. At this point, however, we assume that number of hospital could satisfy the capacity required.

Pairs of strings create strings of health centers after strings of hospital in which they are running. Also in locating health centers, we may want to make a balance between the demand and the capacity of a health center. The capacity of health center is provided by total health check in a day. The capacity simply in formulation can be transferred to the sense of strings as the given number of health centers.

As indicated above, each string may work in the same numbers of nodes, which indicates that the strings here the same length. In this manner, string of health center site is produced after string hospital site. The string of health center site is accepted if all candidate site of health centers was covered. The condition of covered catch each gene "1". The first gene "1" of health center site will seek to all gene of hospital candidate site in which it will be satisfied if at least one hospital can cover the health center. After that, the searching will move to next gene "1" of health center site to do the similar work as before. This iteration will be repeated until the above condition is fulfilled. This two strings have locus with load of gene "1" without overlapping, that is, it does not choose the same candidate site for locating two different facilities. Interaction of two strings will be coming on each gene "1" which it contains the physical meaning location-allocation. In order to show these relations, figure 7 could be held as some illustrations.

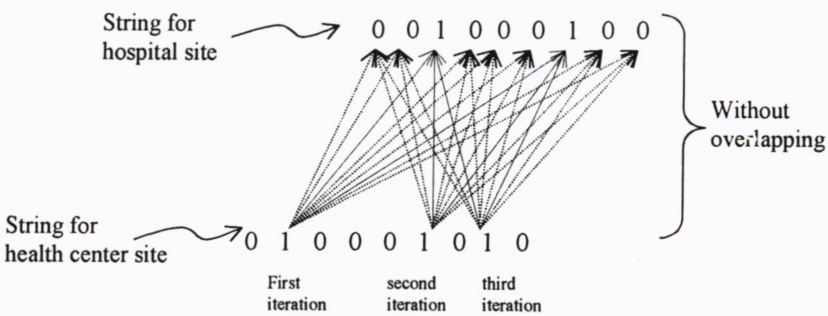


Figure 7. A Part of the Relationship of Two Strings

These two strings also will be used for referral patients from health center to hospital, that is, the string of health center become new patient node for hospital side. At this stage, the gene "1" in string of health center will search the nearest hospital for allocating the referral patients. Before it happens, these two strings work to catch the objective function in the part of allocating node i to the nearest facility. In this case, if there is a health center located in candidate site k, the nearest demand node i should be allocated to that health center. In another case, if there is a hospital located in candidate site j, the nearest demand node i should be allocated to that hospital. After that, referral patients at health center site k can be assigned to a hospital at site j.

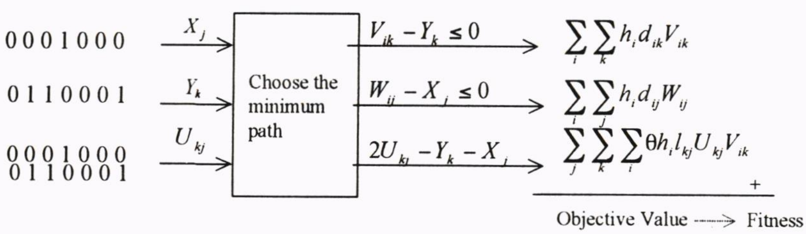


Figure 8. Two Strings and their Value in Objective Function

In the first solution, for the first term of the objective function (for allocation health center), we substitute location variables from second string. Similarly, for the second term of the objective function, we substitute location variables from first string. To deal with the constraint that requires each node i to be assigned to exactly one facility either hospital or health center, we select the minimum path in which it is assigned to exactly one facility. After this step, the demand is the given variables that we can substitute directly related to node i. Thus, calculation can be done for each term of objective function. Total of these two sub objective function values become the objective function that evaluates patient-weighted distance in each individual. Two strings and their value in objective function may be clearer in figure 8.

We record the objective function value for each individual in term of fitness value. This fitness value shows the objective value in number between 0 and 1. If we are successful in finding a good solution that satisfies efficient allocation of all nodes, we will have fitness value close to 1. These conditions work for each individual in a population of strings. Thus there are, in random, different value of fitness in population. Up to this stage, we have outlined the initialization of calculation procedure, and in what follows we will show the description of GA operations.

One description of genetic algorithms is that they are iterative procedures maintaining a population of individuals that are candidate solutions to a related problem. Reproduction is based on the principle of survival of the fittest. Goldberg (1989) provides that the reproduction is implemented in the function select as a linear search through a roulette wheel with slots weighted in proportion to string fitness values. By exchanging information between two parents, the crossover operator provides a powerful exploration capability. In our case, the method used is called one-point crossover. It defines that the individuals are represented as zero-one string. In one point crossover, a point, called the crossover point, is chosen at random and the segments to the right of this point are exchanged. For example, figure 9 shows crossover operator in our approach.

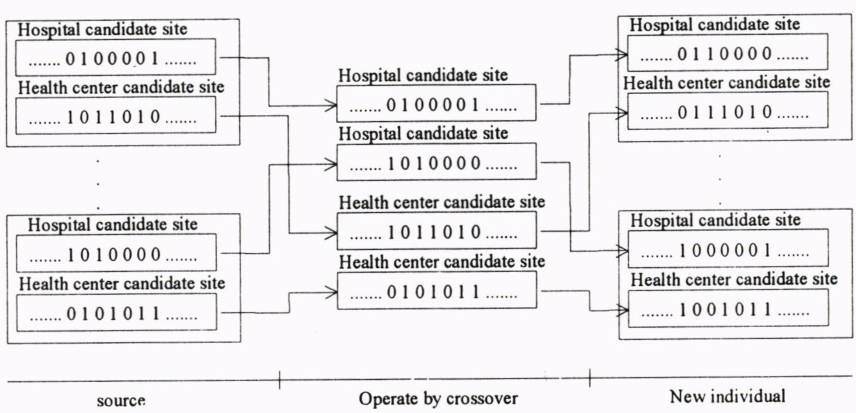


Figure 9. Crossover in Double String

The mutation operator simultaneously works toward the double strings. First, the operators mutate the string of hospital candidate site and then the string of health center. Before approving a new individual, operators have to check all location of health centers under critical coverage distance. If all health centers was covered, it is no need to repeat it again.

5. NUMERICAL CALCULATION ON HALMAHERA NETWORK

Halmahera islands are a part of North Maluku Regency. North Maluku is archipelago regency in Indonesia, which consists of 320 small islands. The total area is 103.789 square kilometers with 22.698 (22%) square kilometers land territory and 81.091 square kilometers (78%) sea territory. These archipelago's location is right in the equator line between 124^0-129^0 east longitude, 30^0 north latitude, and 3^0 south latitude. The islands are divided in to two groups. They are big and middle islands as Halmahera island (18.300 km square), Morotai (2.476 km square), Bacan (2.053 km square), Obi (3.111 km square), Taliabu (3.193 km square) and Mangoli (1.286 km square). And the other group is the small islands as Ternate, Moti, Makian, Kayoa, etc. Based on census 1991, total population of North Maluku regency is 568.780 inhabitants. If we compare it with total population on census 1980, the growth rate is about 1,52%. The population is separated equally in 21 subdistrics and 320 islands. The Halmahera island, which is 80% of North Maluku regency area, only 40% from whole population in regency. In spite of that the magnitude of population are spreading in many small islands around Halmahera island. Our network for studying was built for the south part of Halmahera island, Obi islands, Bacan islands, and Kayoa islands as shown in the original map in figure 10 and figure11. There are a lot of towns and villages in this area but there is no hospital. This is one of motivations for us to try to apply the model to this area.

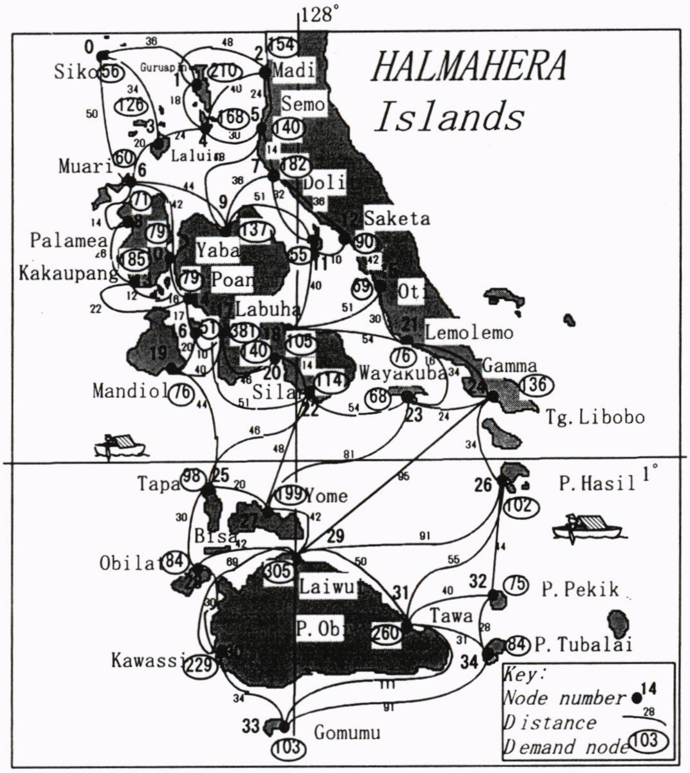
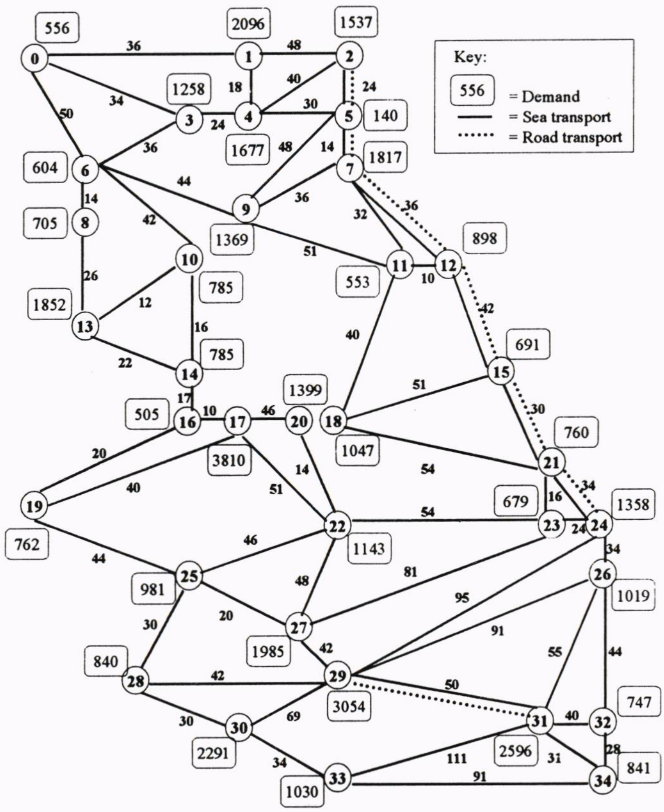


Figure 10. Map of Halmahera Island

In construction of the network for studying, we assume that demands and travel between demand sites and facilities are assumed to occur only on a network or graph composed of nodes and links. We also assume that demands occur only at the nodes of the network, though some network location models have permitted demands to be generated anywhere on the links of the network. In network location models, facilities can be located only on the nodes or links of the network. Also, a network model should be established based on: (1) real situation and practical, (2) number of towns and villages, (3) number of links should be considered, and (4) demand in related node.

Almost all of the villages are sited on the beach. Small vessels for travelling in water, which are moved by oars, sails or motors are used in the area of North Maluku regency. This transportation mode connects each village. Road transportation also important in wide plain area. However, in the current condition, a patient should transfer from a boat to ferry or airplane to go to the hospital site.

The geographical constraints appear in efforts to improve physical infrastructure for health service in the area of Halmahera Islands, because that area consists of hundred islands and mountains. Commonly, developing countries has limited funds allocated to the health sector. To deal with that realistic situation in Halmahera network, we assume the number of hospital to be allocated is 3 with approximately more than 35 beds for each hospital. Consequently, the number of health center can be associated with the capacity of hospital. It suggests that the number of health centers to be allocated will be 12.



Link distance value written to kilometer

Figure 11. A Network Model

According to the official report regarding the prevention and control of locally endemic disease in the country that has influenced health an official report has indicated that:

(1) Malaria; Improvement of malaria surveillance and enlargement of transmigration area and technical irrigation of rice field give positive impact.
(2) Leprosy; The prevalence of leprosy was 0.36 in 1992 and 0.19 in 1995.
(3) Diarrhea; The reported incidence rate of diarrhea in 1992 was 25.4% and in 1995 24.1%. Mortality rate of diarrhea in infant in 1986 was 13.3‰. Mortality rate caused by diarrhea in infant in 1992 was 7.3‰ and in children less than 5 years was 4‰.
(4) Lung Tuberculosis; Achievement of conversion and cure rate in some basic units more than 80%.

The implementation of equity in health delivery system may have a positive impact on the case finding.

Based on physical infrastructure data presented by Ministry of Health Republic of Indonesia during 1986 until 1995, the ratio of the number of hospital and health center is estimated as 1 : 6. Data was recorded without separating land area and small island area. In particular, in advance country the number of bed in a hospital started from 21 beds until 815 beds. And the rate of patients (concerned with referral patients) in average are equal 0.165%.

As indicated in the formulation, the problem always pointed out a set of connecting calculation in a given demand and its minimum distance access to facilities. Also, such a behavioral perspective leads us to a clear delineation of location goals within a given coverage distance. To deal with a fixed coverage distance, we can run a set of searching location of hospital and health center in term of hierarchy.

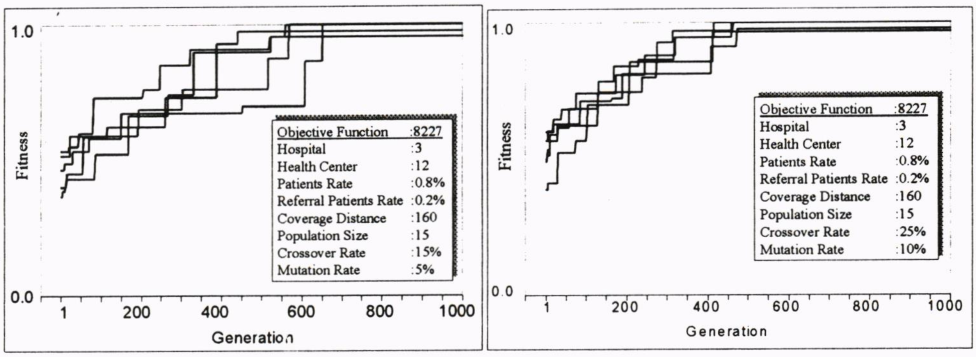


Figure 12. Calculation Results of 5 Times Trial with Variation Value of Parameter

Some results are as follow. The work of GA for changing facility site is strongly related to the rate of crossover and mutation. The process of iterations is running in a number of generations as an area of searching. Trial for searching location of 3 hospitals and 12 health centers within related network are shown in figure 12.

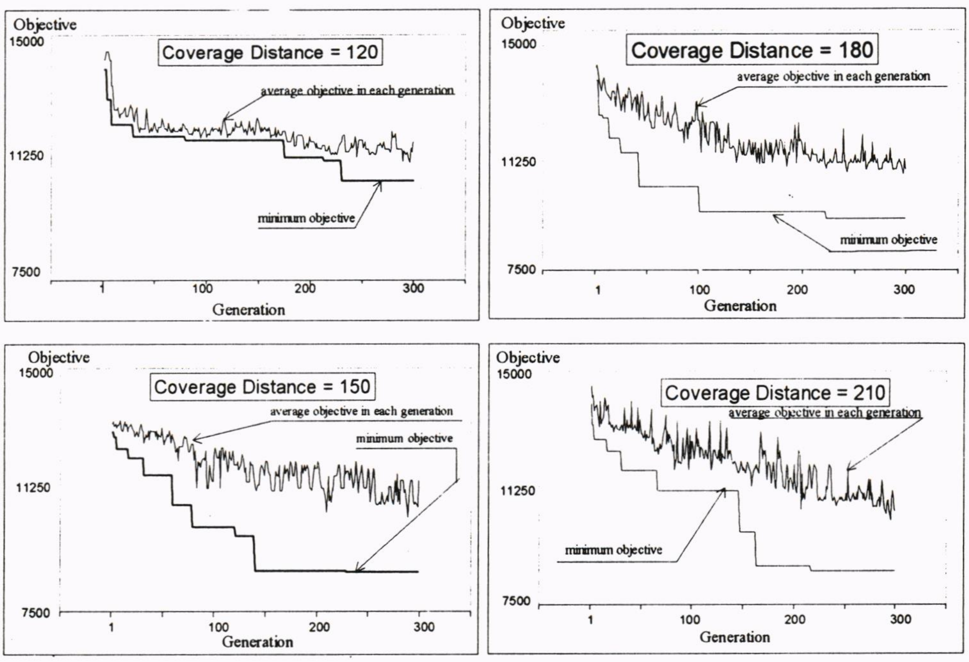


Figure 13. GA Performance and Variation of Coverage Distance

The parameter of coverage distance also determines the area of searching. It follows that the combination of sites of facility tends to be difficult in a small coverage distance (see figure 13). Alternatives for locating these facilities and the diagram patient flows in Halmahera islands are given in figure 14. The flow pattern may result from the facility site. By this diagram, we can see that the patients in each village should flow through the system with a selected link. Each health center collects the nearest demands and establishes a small group of villages. Similarly, each hospital also establishes a group, which contains the nearest villages and the nearest health centers for receiving the referral patients. The location of hospitals determines the separation of the hierarchical activity.

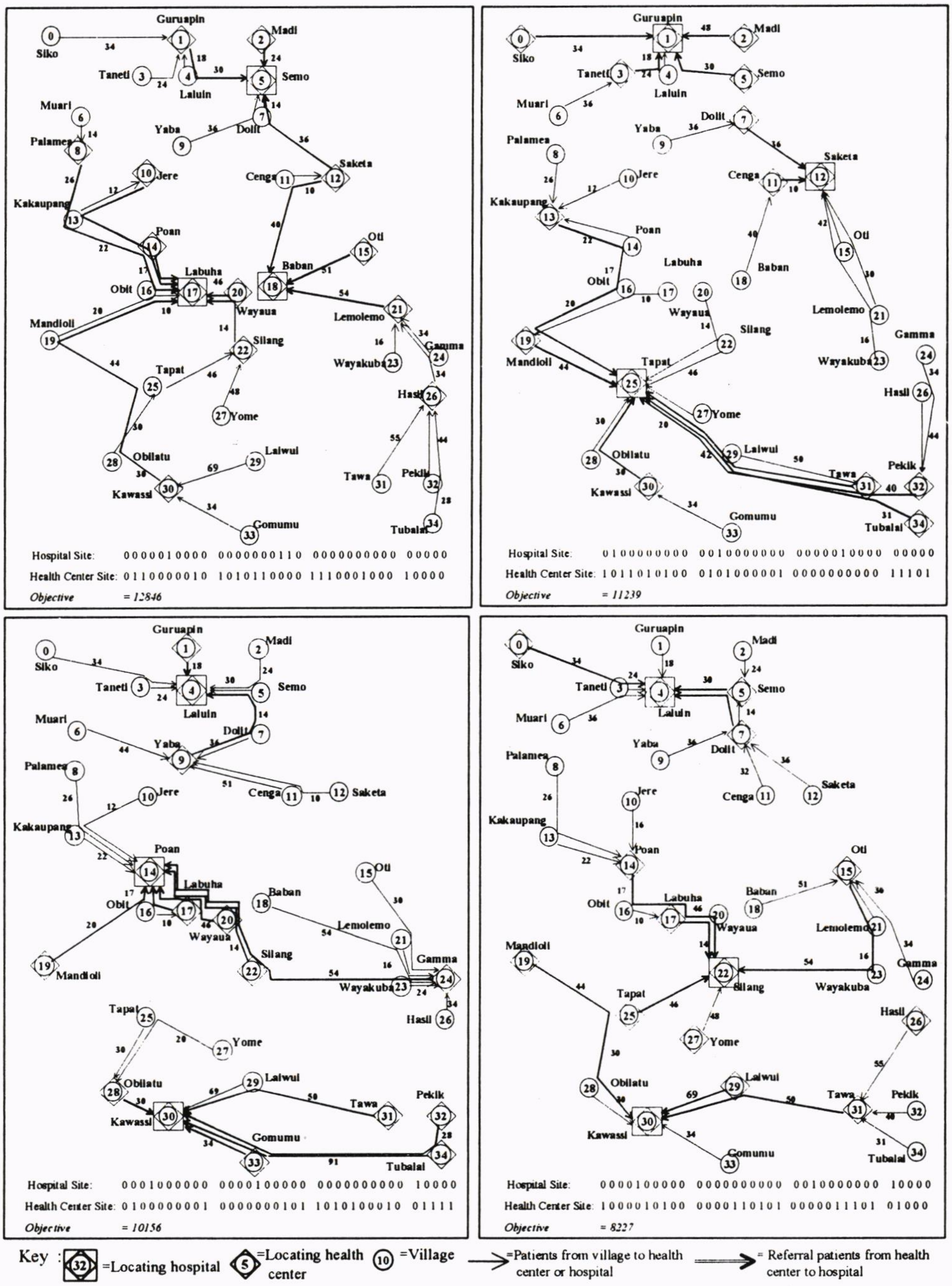
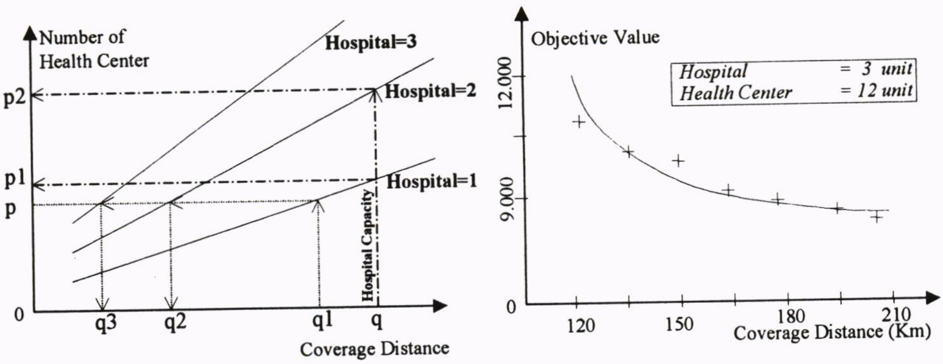


Figure 14. An Alternative Location and Patients Flows Diagram

In such a case, it is shown that number of hospital can reduce the value of coverage distance, described in figure 15(a). For example, for H=1 and coverage distance is equal q1, the number of health centers (p) are same with the q2 value of coverage distance for H=2, and also same in the relation of H=3 and q3 value of coverage distance. Another fact, the increasing number of hospital can be able to lead the increasing number of health center. For example, in the q value of coverage distance, number of health center (p1) for H=1 lower than number of health center (p2) for H=2. When we consider only a single hospital, the increasing of coverage distance, the increasing of hospital capacity. Figure 15(b) shows that it is easy to find optimum value in some value of coverage distance.



(a) (b)

Figure 15. (a) Interaction between Coverage Distance and Number of Health Center, (b) Interaction between Objective Function and Coverage Distance

6. CONCLUSION

Hospitals and health centers play an important role in the hierarchical health care activity. The implementation gives the feature of the model and the performance of the capability and efficiency of GA approach in searching minimum objective value of patients weighted distance as a reflect of locating these facilities in demand node precisely. We showed the GA performance in a network with 35 nodes, and its capability and efficiency as well. The speed of the algorithm depends on the level of competition among value of parameter in each generation, and may be also concerned with the computer languages. For all the experiments the CPU time ranged from second to several minutes (less than 10 minutes).

From application results to Halmahera Islands, it is shown that the most important variable in the location problem in health-care facilities is coverage distance. In order to improve the current situation of Halmahera Islands with regards a coverage distance, it can be said that the provision of transport facility is urgent government policy.

The relation between the allocation fund for the construction and the number of facilities is not taken into account in the model. Otherwise, the result of patient flows can inform us which links can be improved for the accessibility. Basically, the local government has to choose between increasing the number of facilities or improving the accessibility. In the case like Halmahera Islands, it also has very limited funds allocated to the health sector. Thus, the next important step for extending the model in health care system is to assist in qualifying the tradeoff decision of local government.

The approach presented here can serve primarily as aid of the health planner in choosing the solution method of health care facility location based on the related problem. Although the formulation has been paid attention to a health care facility location system, the result of this study may be plausible and applicable to a number of other systems with similar features, including fire station, post office location system, and so on. For example, post office location system, the same model and its calculation procedure might be applied with some conditions, these are, the customers are not patients and the relation of two strings may change in the calculation procedure.

Since we are not dealing with allocation of demand to facilities decided by demand, future studies will focus on this point. Therefore users' behavior based on spatial interaction (gravity) effect, that is, user attracting facilities as evaluated in Mayhew and Leonardi (1982) will be considered. It is interesting, at this point, to model location problems in new dimensions, like those in multilevel, multiactivity, and multistage (dynamic) systems.

REFERENCES

1. Ammari, F. Suzuki, T. Miyagi, T. (1998) Application of GA on Location of the Health Care Facilities. **Proceedings 21st Infrastructure Planning Conference of JSCE,** Siga City, Japan, November 21-23, 1998, 125-128.
2. Daskin, Mark S. (1995) **Network and Discrete Location**. John Wiley & Sons, Inc., New York.
3. Eitan, Yair, Narula, Subhash C., and Tien , James M. (1991) A Generalized Approach to Modeling the Hierarchical Location-Allocation Problem, **IEEE Transactions on System, Man, and Cybernetics, Vol. 21, No. 1**, 39-46.
4. Girt, John L (1973) Distance to General Medical Practice and Its Effect on Revealed Ill-Health In A rural Environment, **Canadian Geographer, XVII, 2,** 154-166.
5. Goldberg, D. (1989) **Genetic Algorithm in Search, Optimization, and Machine Learning**, Addison-Wesley, New York.
6. Gore, C. G. (1991) Location Theory and Service Development Planning: 'Which Way Now?' **Environment and Planning A,Vol.23**, 1095-1109.
7. Health Resources (1997) Ministry of Health of Republic Indonesia.
8. Hodgson, M J (1986) A Hierarchical Location-Allocation Model with Allocations Based on Facility Size, **Annals of Operations Research, No.6**, 273-289.
9. Leonardi, G. (1981) A Unifying Framework for Public Facility Location Problems-Part 1: A Critical Overview and Some Unsolved Problems, **Environment and Planning A, Vol.13**, 1001-1028.
10. Mayhew, L D and Leonardi G, (1982) Equity, Efficiency, and Accessibility in Urban and Regional Health-Care Systems, **Environment and Planning A, Vol.14**, 1479-1507.
11. Monograph of North Maluku Regency (1993) State Department of Republic Indonesia.
12. Moore, George C. and ReVelle, Charles (1982) The Hierarchical Service Location Problem, **Management Science Vol. 28, No. 7**, 775-780.
13. Ruth, R. Jean (1981) A Mixed Integer Programming Model for Regional Planning of a Hospital Inpatient Service, **Management Science, Vol. 27 No. 5**, 521-533.
14. Storbeck, J. (1982) Slack, Natural Slack, and Location Covering, **Socio-Econom. Planning Sci. 16**, 99-105.