Asian Journal of Innovation and Policy (2019) 8.1:122-140
DOI: http//dx.doi.org/10.7545/ajip.2019.8.1.122

Restructuring Primary Health Care Network to Maximize Utilization and Reduce Patient Out-of-pocket Expenses

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Abstract Providing free primary care to everyone is an important goal pursued by many countries under universal health care programs. Countries like India need to efficiently utilize their limited capacities towards this purpose. Unfortunately, due to a variety of reasons, patients incur substantial travel and out-of-pocket expenses for getting primary care from publicly-funded facilities. We propose a set-covering optimization model to assist health policy-makers in managing existing capacity in a better way. Decision-making should consider upgrading centers with better potential to reduce patient expenses and reallocating capacities from less preferred facilities. A multinomial logit choice model is used to predict the preferences. In this article, a brief background and literature survey along with the mixed integer linear programming (MILP) optimization model are presented. The working of the model is illustrated with the help of numerical experiments.

Keywords Facility location, primary care, public health, optimization, out-of-pocket expenses

I. Introduction

Standards of public health care delivery systems need improvement, especially in developing countries (the focus of this article). There are many impediments that are difficult to overcome. Inadequate capacity is one major constraint. Physical infrastructure can be built with new investments, but getting large numbers of trained health professionals within a short time span is impossible. Therefore, it is important to utilize the existing capacity in the best possible way. The importance of primary health care is understood by all. Government facilities, namely, primary health centers (PHCs) and community health centers (CHCs) provide free primary care. In developing countries,

Submitted, January 22, 2019; 1st Revised, April 3, 2019; Accepted, April 4, 2019
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publicly-funded facilities face issues of minimal infrastructure, scarcity of medicines and medical staff, etc. (Agarwal et al., 2017). Most of them are either over crowded or underutilized. Patients also do not often have a good impression about the quality of care at these institutions. As a result, most patients, even those from poorer background, opt for expensive private health centers for primary care (Sangar et al., 2018). In the process, they incur out-of-pocket expenses along with the cost on travel, etc. This cost can discourage many from even seeking basic care (Balarajan et al., 2011; Goli et al., 2016).

The primary health centers are considered the first point of contact between patients and medical staff and therefore have important preventive and curative roles. The present situation of primary care centers calls for reorganization of existing facilities and tapping new resources. The potential of each facility needs to be reassessed based on their ability to attract patients. Attractiveness can be improved by locating them nearer to localities and providing health service that reduces patient out-of-pocket expenses. Facilities with less potential need to be downgraded and their excess capacity can be reallocated.

The performance of a health care system can improve, if the choice of patients is given due importance. Zhang et al. (2016) proposed a methodology for a medical care diagnostic service provider to analyze the attractiveness factors driving patient preference when they choose a diagnostic center for laboratory tests. Zhang et al. (2012) considered the choice of a target population for designing a preventive health care facility network, and the proximity to a facility was assumed to be an attractiveness factor. They have not considered the out-of-pocket expenses of the patients and to the best of our knowledge, most of location selection modeling literature has ignored this important determinant for choice.

We propose an optimization model where the objective is to maximize the likelihood of utilization of public health care facilities by the target population. The model considers the choice of the population determined by out-of-pocket expenses and travel cost. The model seeks to identify those public facilities which require expansion, and those with limited potential for down-gradation. In the next section, we briefly review the literature on the theme of this article. In section 4, an optimization model is proposed for the decision-making problem. Results from numerical experiments and their implications are given in section 5.

II. Related Work

Out-of-pocket expenses (OOPE) are incurred directly or indirectly by the patients for getting health care services. OOPE can include direct expenses, such as, fees for consultations, medicines, laboratory tests along with cost of accommodation, transportation, food, etc. (Hamid et al., 2014). The National Health Accounts of India issued in October 2017 found that individual households have contributed more than 62% towards financing of health care in the country during the year 2014-15 (NHSRC, 2017). Sangar et al. (2018) found that the impact of OOPE on poverty was higher in rural households. While the big hospitals remain overcrowded, the public primary care system remains inefficient because of poor quality, uneven utilization due to inappropriate location, etc. This forces the population towards using private health care facilities resulting in an increase in OOPE (Kumar et al., 2011).

Powell-Jackson et al. (2013) conducted a study to measure the quality of primary health care facilities in India and found that most centers do not even meet the minimum standards. Another study (Salazar et al., 2016) has found patients bypassing nearby primary health care facilities and visiting more expensive private care providers. Poor infrastructure, shortage of medicines, unavailability of service providers, physical inaccessibility are some of the factors responsible for the poor utilization of publicly funded facilities (Goli et al., 2016; Agarwal et al., 2017).

Services at the publicly-funded primary care facilities are given free of cost. If the facilities are improved at these centers, their utilization could be higher. For example, the presence of more health service providers at centers is correlated with lower level of bypassing by the patients. In order to increase footfall, more investment is needed along with better allocation of limited resources like physicians. Reallocating the capacities of public facilities might be considered as one way to deal with this concern and thereby encouraging the patients to use public clinics. Rao and Mant (2012) stresses on the strengthening of capacity to improve a primary care system with the aim to deliver universal services at reduced cost.

A typical health care system is hierarchical in nature and the severity of disease treated there determines the levels in the hierarchy. While the lower-level facilities offer most basic and preventive care services, higher-level facilities provide more critical and mostly in-patient services. Patients visiting a higher-level facility are generally referred through lower-level facilities. Moore and ReVelle (1982) proposed a location model for the basic hierarchical system with two types of facilities. Ratick et al. (2009) have applied this model in Kohat district of Pakistan for locating medical facilities.

Wang et al. (2003) addresses the problem of change in customer demand that disturbs the efficiency of existing systems and consider simultaneous opening and closing of facilities. Araya et al. (2012) have analyzed a similar problem in the context of schools and addressed the issue of uneven utilization. They proposed an integer linear programming problem for giving suggestions on rural schools in Chile. Monteiro and Fontes (2006) discussed bank-branch restructuring problem, where the main objective was cost minimization by maintaining / re-sizing / closing existing branches or opening new branches, and a local search heuristic was also presented for solving the model. Dias et al. (2006) discussed a location-allocation model dealing with opening, re-opening and closing of facilities. Basar et al. (2017) conducted a case study in Turkey for finding the location of bank branches, they presented some decision support methodology for the location of bank branches and a mathematical programming model was proposed which dealt with opening and closing of bank branches simultaneously thereby finding best locations by evaluating the performance of the existing branches.

Guerriero et al. (2016) proposed optimization models for rearranging the public health system in the northern part of Calabria, Italy, with the aim to improve the efficiency of the existing health care system. Bruno et al. (2016) have proposed a location model to bring in rationality in the public sector facilities. The model assumed to close some facilities for increasing system affordability and thereby reallocating the demand to facilities remaining in the system. Ruiz-Hernandez (2014), Ruiz-Hernandez et al. (2015) proposed capacitated model for closing and re-sizing the bank branches after mergers and acquisitions.

Antunes and Peeters (2001) discussed a multi-period facility location model for finding best locations by opening new facilities and closing some existing ones along with expanding and contracting existing facilities. Jena et al. (2015a; 2015b; 2016) discussed location problems considering capacity-adjustment of existing facilities. All these articles are concerned with restructuring the given network of facilities. A trained manpower, especially physicians, is available only in limited numbers. For developing countries, training and recruiting doctors for primary health services within a short time frame is nearly impossible. Therefore, reallocation of limited resources among new and existing facilities should be decided concurrently with the restructuring process.

This article is concerned with an important decision-making problem: which of the existing facilities should be upgraded or which are to be downgraded. The objective for this initiative is to reduce patient out-of-pocket expenses. This problem has high social relevance for developing countries. The model proposed in this article deals with issues like limited availability of critical resources, choice determinants of patients and cost of primary care, within a single framework. Such a study is done for the first time in the Indian context.

III. Problem Description

In India, public financed primary health services are provided through primary health centers (PHCs) and community health centers (CHCs). But due to their limited numbers and other reasons discussed earlier, many patients visit private practitioners while incurring extra cost. Most government tertiary care hospitals also reluctantly provide curative primary care to satiate the capacity shortfall. Lately, policy-makers are realizing the importance of a functional primary care system in achieving universal health care goals. For this reason, the availability and utilization of PHCs and CHCs need to increase rapidly.

This study is concerned with a decision maker who has to decide on the status of PHCs and CHCs under her jurisdiction. Though both types of facilities offer similar curative and preventive care, CHCs are larger facilities in comparison to PHCs and have better infrastructure and more resources. They are supposed to be more attractive. But a patient would prefer a PHC to a CHC if the former is located much closer to her. The decision maker can upgrade the status of a PHC to CHC and vice-versa to improve their overall utilization while achieving other intrinsic objectives and constraints.

Patients incur out-of-pocket expenses for getting primary care services. The magnitude of cost influences the choice of facility. These costs are incurred on account of travel for medication and can include the cost due to waiting for service. As CHCs have more resources, the expected cost to a patient visiting them would be lesser than at PHCs, assuming other factors remain constant. The decision maker has the objective of minimizing the total out-of-pocket expenses (OOPE) for all users of PHCs and CHCs and costs for conversions of PHCs into CHCs and vice-versa. This total cost is termed ’societal cost’ in the next section.

Space and infrastructure are added to PHCs for upgrading them to CHCs. The cost for such enhancements is known. Similarly removal and disposal cost due to down-gradation is also known. A budget is available for these projects. If a PHC is upgraded, additional physicians are needed; on the other hand, physicians would be available for reassignment elsewhere after a down gradation. If needed, the decision maker can recruit a limited number of new physicians. An optimization model is proposed in the next section for the problem described above.

IV. Model Development

Consider a region (a city or a district) where primary health care is provided by publicly-funded facilities. These facilities where service is free are of two types: primary health centers (PHCs) and community health centers (CHCs). CHCs are larger than PHCs and provide additional facilities like medical diagnostics and consultation with specialists. People live in many localities of the region and patients from a locality i choose a health care facility according to the following multinomial logit (MNL) choice model (Zhang et al., 2012):

$$X_{ij}^{r} = \frac{e^{-\beta(t_{ij}+ E_j^r)}Y_j^r}{1 + \sum_{l\in J}\sum_{r\in R} e^{-\beta(t_{il}+ E_l^r)}Y_l^r} \qquad (1)$$

The expression (1) written above can be rewritten in the following form:

$$X_{ij}^{r} + \sum_{l\in J}\sum_{r\in R} e^{-\beta(t_{il}+ E_l^r)}X_{ij}^r\, Y_l^r = e^{-\beta(t_{ij}+ E_j^r)}Y_j^r \qquad (2)$$

X_{ij}^r is a continuous variable and Y_j^r is a binary variable. Therefore, linearization of (2) could be done by introducing an artificial variable Z_{ijl}^r as follows (Zhang et al., 2012):

$$X_{ij}^{r} + \sum_{l\in J}\sum_{r\in R} e^{-\beta(t_{il}+ E_l^r)}\, Z_{ijl}^r = e^{-\beta(t_{ij}+ E_j^r)}Y_j^r \qquad (3)$$

$$Z_{ijl}^r \le X_{ij}^r \qquad \forall\, i \in I \qquad j,l \in J \qquad r \in R \qquad (4)$$

$$Z_{ijl}^r \le M_1\, Y_l^r \qquad \forall\, i \in I \qquad j,l \in J \qquad r \in R \qquad (5)$$

$$Z_{ijl}^r \ge X_{ij}^r - M_2(1 - Y_l^r) \qquad \forall\, i \in I \qquad j,l \in J \qquad r \in R \qquad (6)$$

$$Z_{ijl}^r \ge 0 \qquad \forall\, i \in I \qquad j,l \in J \qquad r \in R \qquad (7)$$

Where, X_{ij}^r is the probability that patients in locality i, ($i \in I$) will visit a facility of type r, ($r \in$ R) at j, ($j \in J$). Y_j^r is a binary variable that indicates whether a facility of type r exists at j and E_j^r is the expected out-of-pocket expense for a patient there. t_{ij} is the cost to travel between $i \in I$ and $j \in J$. β is a parameter of the MNL model and can be estimated externally. M_1 and M_2 are very large numbers.

1. Cost to Society

The condition of public health systems in developing countries is pitiful and the patients do not find public facilities to be capable enough to meet their health care requirements due to varied reasons like uneven presence of staff, quality related issues, insufficient infrastructure, etc.(Kumar et al., 2011; Hamid et al., 2014; Ladusingh et al., 2018). The patients are thus forced to pursue costlier facilities or facilities located at far-off places that increase their out-of-pocket expenses. The economically weaker section of society is suffering the most and is moved deeper into poverty as a result of rising out-of- pocket expenses (Garg and Karan, 2008; Balarajan et al., 2011), and the situation is even worse in the rural areas (Sangar et al., 2018). It is therefore necessary to look for ways to bring down out-of-pocket expenses with a view to provide affordable health care to all. We propose a model aimed at minimizing the cost to society, which consists of out-of-pocket expenses and cost incurred for capacity management. Travel cost, cost incurred on consultation, medicines, etc., are part of out-of-pocket expenses whereas the cost incurred for capacity management includes costs incurred on upgrading and downgrading the lower level PHCs and higher level CHCs, respectively. The objective function (8) minimizing the total social cost is given below:

$$\text{Minimize}[\sum_{i\in I} P_i \sum_{j\in J}\sum_{r\in R}(t_{ij} + E_j^r)X_{ij}^r + \sum_{j\in J} C_j^u U_j + \sum_{j\in J} C_j^d D_j] \tag{8}$$

Where, P_i is demand for health care in zone $i\in I$; U_j and D_j are binary variables indicating up-gradation and down-gradation respectively at $j\in J$; C_j^u and C_j^d are costs of up-gradation and down-gradation respectively at $j\in J$.

2. Capacity Management

The existing public health system is finding it difficult to cope with increased demand for health care as a result of a soaring population, and this makes patients visit costlier facilities for health-related services, which increases the out-of-pocket expenses (Saksena et al., 2010; Ladusingh et al., 2018). The public health system needs to be improved especially to meet the needs of the underprivileged population at minimal cost (Sohrabi and Tumin, 2016). There is a need to transform the existing set-up of public facilities to make it more cost effective.

Graber-Naidich et al. (2017) proposed a model focused on improving distribution of health professionals by restructuring residency-training system in order to have adequate health professionals serving the rural and underserved communities. We have incorporated the concepts of up-gradations and down-gradations to look after this issue. The model addresses the lower level PHCs and higher level CHCs requiring up-gradations and down-gradations, respectively. Conditions (9) to (14) given below will determine the present PHCs to be upgraded and present CHCs to be downgraded.

$$Y_j^p \leq 2 - (M_j + N_j + U_j) \quad \forall j \in J \quad (9)$$

$$1 - Y_j^p \leq M_j + N_j - D_j \quad \forall j \in J \quad (10)$$

$$Y_j^c \leq 2 - (M_j + N_j + D_j) \quad \forall j \in J \quad (11)$$

$$1 - Y_j^c \leq M_j + N_j - U_j \quad \forall j \in J \quad (12)$$

$$1 - Y_j^p \geq N_j - D_j \quad \forall j \in J \quad (13)$$

$$1 - Y_j^c \geq M_j - U_j \quad \forall j \in J \quad (14)$$

Where, M_j and N_j specify the existence of a PHC and a CHC respectively at $j \in J$ in the present situation; Y_j^p and Y_j^c are the binary variables indicating the existence of a PHC and a CHC respectively at location $j \in J$ after up-gradations and down-gradations.

3. Model

Patients give preference to a facility where they incur the minimum cost (travel cost plus the treatment cost). The treatments at publicly-funded facilities are free, yet patients incur direct and indirect costs for medicines, medical diagnostic services, long waiting time, etc. It is assumed that out-of-pocket expenses at CHCs are lower than PHCs. In this decision-making problem, the policy-maker intends to increase the use of publicly-funded facilities. It has to decide how many PHCs to be upgraded to CHCs. It can also downgrade some present CHCs so that the total resource requirement (especially trained medical doctors) is small. To make this decision, the following set covering probabilistic choice optimization model is proposed.

$$\text{Minimize } [\sum_{i \in I} P_i \sum_{j \in J} \sum_{r \in R} (t_{ij} + E_j^r) X_{ij}^r + \sum_{j \in J} C_j^u U_j + \sum_{j \in J} C_j^d D_j] \quad (15)$$

Subject to

$$Y_j^p \leq 2 - (M_j + N_j + U_j) \quad \forall j \in J \quad (16)$$

$$1 - Y_j^p \leq M_j + N_j - D_j \qquad \forall j \in J \qquad (17)$$

$$Y_j^c \leq 2 - (M_j + N_j + D_j) \qquad \forall j \in J \qquad (18)$$

$$1 - Y_j^c \leq M_j + N_j - U_j \qquad \forall j \in J \qquad (19)$$

$$1 - Y_j^p \geq N_j - D_j \qquad \forall j \in J \qquad (20)$$

$$1 - Y_j^c \geq M_j - U_j \qquad \forall j \in J \qquad (21)$$

$$U_j + D_j \leq 1 \qquad \forall j \in J \qquad (22)$$

$$Y_j^p + Y_j^c = 1 \qquad \forall j \in J \qquad (23)$$

$$U_j \leq M_j \qquad \forall j \in J \qquad (24)$$

$$D_j \leq N_j \qquad \forall j \in J \qquad (25)$$

$$M_j + N_j = 1 \qquad \forall j \in J \qquad (26)$$

$$X_{ij}^r \leq Y_j^r \qquad \forall i \in I, j \in J, r \in R \qquad (27)$$

$$\sum_{j \in J} U_j \leq \sum_{j \in J} D_j + \alpha \qquad (28)$$

$$\sum_{j \in J} \sum_{r \in R} X_{ij}^r \leq 1 \qquad \forall i \in I \qquad (29)$$

$$M_j, N_j, U_j, D_j \in [0,1] \qquad \forall j \in J$$

$$Y_j^p, Y_j^c \in \{0,1\} \qquad \forall j \in J$$

$$X_{ij}^r \geq 0 \qquad \forall i \in I, j \in J, r \in R$$

The notations used in this model are as follows: J represents the set of all locations of public facilities (PHCs and CHCs); R= {PHC, CHC}, i.e. R represents type of public facility. P_i is demand for health care in zone $i \in I$. C_j^u and C_j^d are costs of up-gradation and down-gradation respectively at $j \in J$; M_j and N_j specify the existence of a PHC and a CHC respectively at $j \in J$. The number α represents number of additional doctors to be hired. The variables in the model are: U_j and D_j are binary variables indicating up-gradation and down-gradation respectively at $j \in J$. Y_j^p and Y_j^c are the binary variables indicating the existence of a PHC and a CHC respectively at location $j \in J$ after up-gradations and down-gradations.

The objective function (15) minimizes cost to the society in the context of health care services. Constraints (16) to (21) determine which among the present publicly-funded PHCs to be upgraded and vice-versa. Constraints (22) to (26) ensure that up-gradation and down-gradation are carried out at appropriate facilities. Constraint (27) represents contingency conditions. Constraint (28) restricts the number of up-gradations to be less than or equal to number of down-gradations plus physician requirement. Constraint (29) is the covering constraint.

V. Validation of the Proposed Model

In this section, we discuss the results of an implementation of the proposed optimization model. In the example, it is assumed that there are twenty population zones and ten public facilities. The matrix given in Table 1 has the data on population sizes (demand at population zones / localities) and transportation cost (in INR) between each pair of population zone and health center. The optimization model was solved using the software package LINGO. It was observed that allocation of population zones to facilities are different for different values of α and an increase in total coverage is observed when the value of α is increased. The results from the model are presented in Appendix 1 and Appendix 2.

Table 1 Travel cost matrix

Zone	Population of zone	Location of Health center (Cost on Transportation from Health center to zone)									
		H1	H2	H3	H4	H5	H6	H7	H8	H9	H10
P1	30	30	50	40	40	60	50	40	50	30	50
P2	88	30	40	50	30	50	40	40	50	50	20
P3	40	40	60	40	40	50	60	30	30	40	60
P4	43	50	20	50	60	60	30	20	60	50	30
P5	32	60	40	50	40	50	40	60	30	50	60
P6	85	50	30	20	60	60	20	60	20	50	50
P7	99	20	20	30	40	20	20	50	40	60	40
P8	35	30	20	40	40	60	30	60	40	30	50
P9	31	50	40	30	50	50	40	20	20	30	20
P10	32	40	30	20	30	20	20	60	20	50	30
P11	39	30	30	50	60	20	50	30	50	40	20
P12	61	20	20	40	40	50	20	50	50	20	20
P13	50	60	60	20	20	30	30	30	40	60	60
P14	96	40	20	30	60	30	30	50	40	50	30
P15	34	20	60	50	50	20	20	50	20	60	20
P16	70	20	30	30	60	40	40	20	30	50	40
P17	75	20	40	20	30	50	50	40	50	50	60
P18	45	30	50	40	50	50	60	30	50	20	30
P19	62	60	60	30	50	40	40	50	60	50	40
P20	33	40	40	60	60	60	60	60	40	20	50

The values in the Appendix are the proportion of respective population visiting a particular PHC/CHC. Appendix1 corresponds to α=0 whereas Appendix2 corresponds to α=5. As displayed in Appendix1, number of PHCs is 8 and number of CHCs is 2 corresponding to α=0 and PHCs and CHCs respectively cover 28.8% and 31.9% of the population and overall coverage is 60.7%. When α=5, then number of PHCs gets down to 3 and number of CHCs becomes 7 and coverage by PHCs reduces to 6.35% and that by CHCs grows to 69.65% and overall coverage becomes 76%.

A significant increase in coverage is observed if a CHC replaces a PHC at a particular site (e.g. in Appendix1, a PHC at site H1 covers 3.7% of overall population whereas a CHC at H1 covers 10.1% of population as shown in Appendix2). Also up-gradation of PHCs to CHCs reduces load from existing CHCs (e.g. in Appendix1, a CHC at site H9 is having a workload of 15.6% which goes down to 9.55% as a result of up-gradations which can be seen from Appendix 2) thereby improving the efficiency of primary care network.

An experiment was conducted to see the influence of the number of up-gradations on the performance of the model. Figure 1 shows the impact of increment in up-gradations on total cost and population covered. It is observed that coverage increases with increase in number of up-gradations whereas total societal cost first decreases with increase in number of up-gradations and then increases. Therefore, an optimal tradeoff between the up-gradation cost and out-of-pocket expense can be determined.

Figure 2 shows that total societal cost is convex with respect to the number of up-gradations. Figure 3 depicts the influence of increase in up-gradations on coverage of PHCs and CHCs, and it is observed that coverage by PHCs decreases whereas coverage by CHCs increases with the increase in the number of up-gradations. Figure 4 displays the ratio of coverage by CHCs and PHCs for each population zone against the number of up-gradations; the graph is showing an increasing trend.

Figure 5 presents the ratio of out-of-pocket expense and travel cost against the number of up-gradations, and the graph displays a downward trend. It shows if no new facilities are established, the contribution of travel cost towards total cost increases gradually by carrying out up-gradations alone.

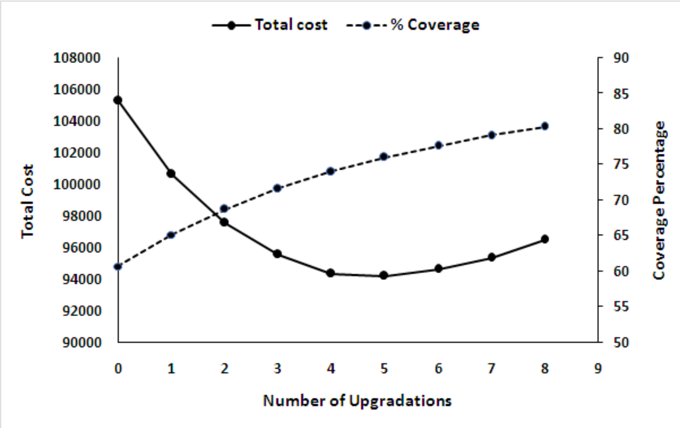

Figure 1 Number of up-gradations vs. Total cost and coverage

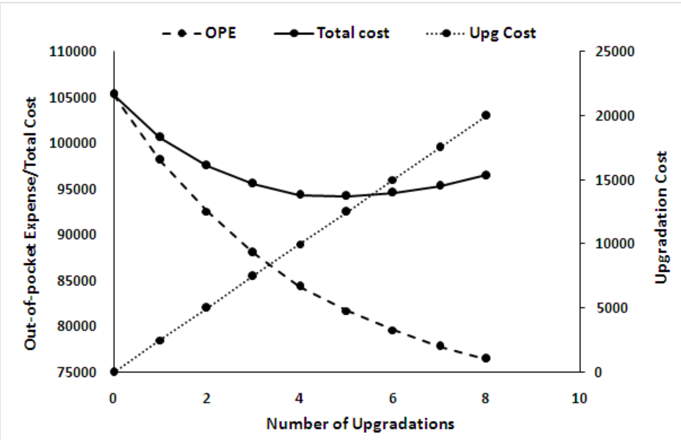

Figure 2 Number of up-gradations vs. OOPE, up-gradation cost and total cost

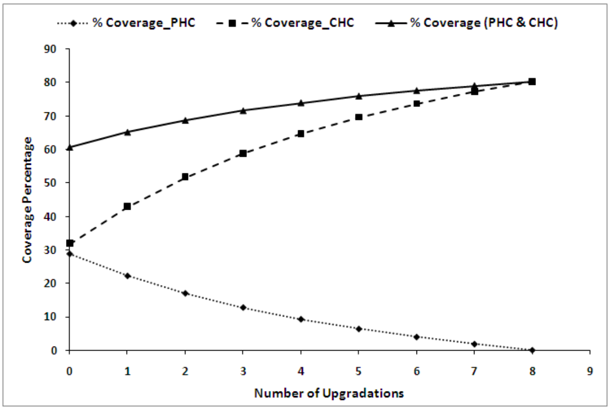

Figure 3 Number of up-gradations vs. Coverage by PHC / CHC / (PHC & CHC)

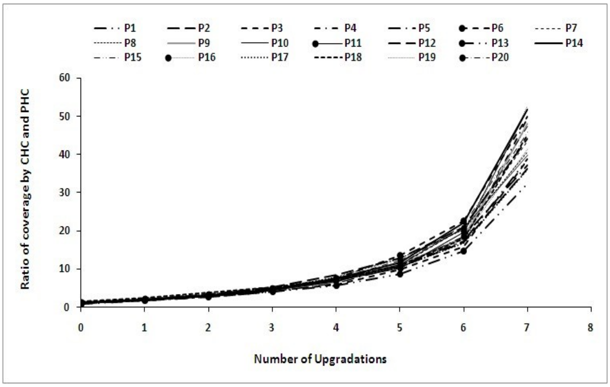

Figure 4 No. of up-gradations vs. Ratio of coverage by CHC & PHC

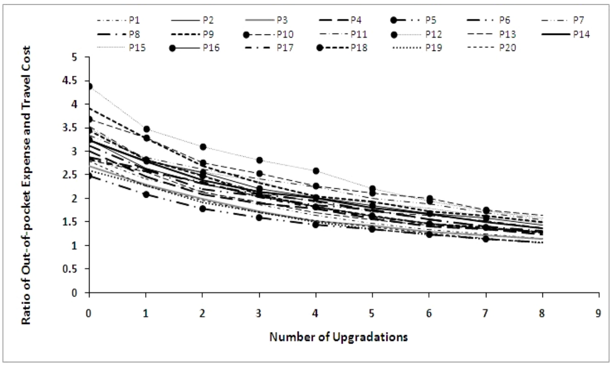

Figure 5 No. of up-gradations vs. Ratio of out-of-pocket Expense &travel cost

Another experiment was conducted by modifying constraint (28) as follows:

$$\sum_{j \in J} U_j = \sum_{j \in J} D_j \qquad (30)$$

Constraint (30) ensures that the number of up-gradations is equal to the number of down-gradations. Figure 6 shows the impact of increment in up-gradations/down-gradations on total cost and population covered. It is observed that coverage curve is concave. This implies re-allocation without increase in total capacity has benefit, but has a limit as well. Consequently, the total societal cost is convex as illustrated in Figure 7. From Figure 6, coverage is maximum and cost is minimum when the number of up-gradations/down-gradations is 3, so it becomes the optimal point.

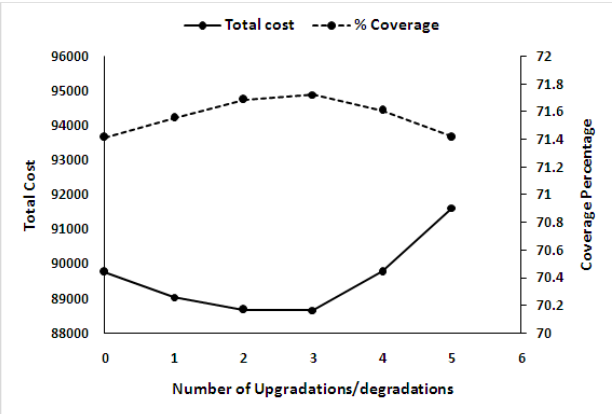

Figure 6 No. of up-gradations/down-gradations vs. Total cost and coverage

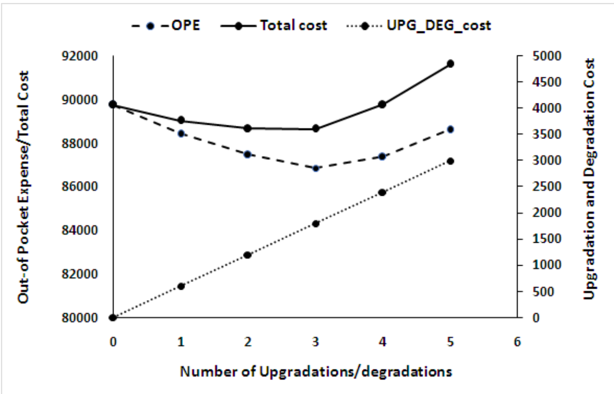

Figure 7 No. of up-gradations/down-gradations vs. OOPE, UPG & DEG and total cost

VI. Conclusion

The model proposed in this article addresses the social concern of increasing out-of-pocket expenses while seeking primary health care. Implementation of the model would help health policy-makers better manage their capacities through optimal up-gradations and down-gradations of facilities at strategic locations. To the best of our knowledge, patient out-of-pocket expenses are considered for the first time in location allocation modeling. The model also includes population choice, which makes it more realistic. Extensive numerical experiments have been conducted by varying model parameters to study their influence on the solution and implications for the decision-maker are drawn. It has been observed that the model could be very helpful in finding the optimum level of investment to achieve maximum coverage. An efficient solution procedure for the model will be developed in future and its performance will be compared against general-purpose optimization software like CPLEX/ LINGO.

Note from Dr Shashi Jain, Chair of COSMAR 2018

Affordable primary care is a major first step towards prevention and cure of patients, and therefore their overall health. Many developing countries face the challenge of poor infrastructure and improper utilization of their publicly funded primary care centers. This paper proposes an optimization model to maximize the utilization of public health care facilities while minimizing the out-of-pocket expenses of the target audience.

The paper was presented in the stream “Marketing and Analytics” of Consortium of Students in Management Research (COSMAR) 2018 that was organized by the Department of Management Studies, Indian Institute of Science. The paper also won the Overall Best Paper Award at COSMAR 18.

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Appendix 1 Solution from Optimization Model at $\alpha = 0$

Zone	Facility: PHC											Facility: CHC											Total (PHC & CHC)
	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	Total	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	Total	
P1	0.04	0.03	0.04	0.04		0.03	0.04	0.03	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.15	0.33	0.60
P2	0.04	0.04	0.03	0.04	0.03	0.04	0.04	0.03	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.19	0.33	0.61
P3	0.04	0.03	0.04	0.04	0.03	0.03	0.04	0.04	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.14	0.30	0.59
P4	0.03	0.04	0.03	0.03	0.03	0.04	0.04	0.03	0.00	0.00	0.28	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.18	0.32	0.60
P5	0.03	0.04	0.03	0.04	0.03	0.04	0.03	0.04	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.14	0.29	0.58
P6	0.03	0.04	0.04	0.03	0.03	0.04	0.03	0.04	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.30	0.60
P7	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.16	0.29	0.61
P8	0.04	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.14	0.32	0.61
P9	0.03	0.03	0.04	0.03	0.03	0.03	0.04	0.04	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.18	0.35	0.63
P10	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.17	0.31	0.62
P11	0.04	0.04	0.03	0.03	0.04	0.03	0.04	0.03	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.19	0.34	0.62
P12	0.04	0.04	0.03	0.03	0.03	0.04	0.03	0.03	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.18	0.36	0.64
P13	0.03	0.03	0.05	0.05	0.04	0.04	0.04	0.04	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.27	0.59
P14	0.04	0.04	0.04	0.03	0.04	0.04	0.03	0.04	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.18	0.32	0.61
P15	0.04	0.03	0.03	0.03	0.04	0.04	0.03	0.04	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.19	0.32	0.61
P16	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.16	0.30	0.61
P17	0.05	0.04	0.05	0.04	0.03	0.03	0.04	0.03	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.14	0.29	0.59
P18	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.17	0.36	0.62
P19	0.03	0.03	0.04	0.03	0.04	0.04	0.03	0.03	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.17	0.32	0.59
P20	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.15	0.34	0.60
Total	0.74	0.73	0.74	0.68	0.70	0.74	0.70	0.72	0.00	0.00	5.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.12	3.25	6.38	12.13

Appendix 2 Solution from Optimization Model at $\alpha = 5$

Zone	Facility: PHC											Facility: CHC											Total (PHC & CHC)
	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	Total	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	Total	
P1	0.00	0.00	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.06	0.11	0.09	0.10	0.00	0.00	0.09	0.00	0.09	0.11	0.09	0.69	0.75
P2	0.00	0.00	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.07	0.11	0.10	0.09	0.00	0.00	0.10	0.00	0.09	0.09	0.12	0.69	0.76
P3	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.00	0.00	0.00	0.07	0.10	0.08	0.10	0.00	0.00	0.08	0.00	0.11	0.10	0.08	0.68	0.75
P4	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.00	0.00	0.00	0.06	0.09	0.12	0.09	0.00	0.00	0.11	0.00	0.08	0.09	0.11	0.69	0.76
P5	0.00	0.00	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.06	0.09	0.10	0.09	0.00	0.00	0.10	0.00	0.11	0.09	0.09	0.68	0.74
P6	0.00	0.00	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.05	0.09	0.11	0.12	0.00	0.00	0.12	0.00	0.12	0.09	0.09	0.71	0.77
P7	0.00	0.00	0.00	0.02	0.03	0.00	0.02	0.00	0.00	0.00	0.06	0.11	0.11	0.10	0.00	0.00	0.11	0.00	0.09	0.08	0.09	0.71	0.77
P8	0.00	0.00	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.06	0.11	0.12	0.10	0.00	0.00	0.11	0.00	0.10	0.11	0.09	0.71	0.77
P9	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.00	0.00	0.00	0.06	0.08	0.09	0.10	0.00	0.00	0.09	0.00	0.11	0.10	0.11	0.71	0.77
P10	0.00	0.00	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.06	0.09	0.10	0.11	0.00	0.00	0.11	0.00	0.11	0.08	0.10	0.71	0.78
P11	0.00	0.00	0.00	0.02	0.03	0.00	0.02	0.00	0.00	0.00	0.07	0.11	0.11	0.09	0.00	0.00	0.09	0.00	0.09	0.10	0.12	0.69	0.76
P12	0.00	0.00	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.06	0.11	0.11	0.09	0.00	0.00	0.11	0.00	0.08	0.11	0.11	0.72	0.78
P13	0.00	0.00	0.00	0.03	0.03	0.00	0.03	0.00	0.00	0.00	0.08	0.08	0.08	0.12	0.00	0.00	0.11	0.00	0.10	0.08	0.08	0.67	0.75
P14	0.00	0.00	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.06	0.09	0.12	0.10	0.00	0.00	0.10	0.00	0.09	0.09	0.10	0.71	0.77
P15	0.00	0.00	0.00	0.02	0.03	0.00	0.02	0.00	0.00	0.00	0.06	0.12	0.08	0.09	0.00	0.00	0.12	0.00	0.12	0.08	0.12	0.70	0.77
P16	0.00	0.00	0.00	0.02	0.02	0.00	0.03	0.00	0.00	0.00	0.06	0.12	0.10	0.10	0.00	0.00	0.09	0.00	0.10	0.09	0.09	0.70	0.77
P17	0.00	0.00	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.07	0.12	0.10	0.12	0.00	0.00	0.09	0.00	0.09	0.09	0.08	0.69	0.76
P18	0.00	0.00	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.06	0.11	0.09	0.10	0.00	0.00	0.08	0.00	0.09	0.12	0.11	0.69	0.76
P19	0.00	0.00	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.07	0.09	0.09	0.12	0.00	0.00	0.10	0.00	0.09	0.09	0.10	0.68	0.74
P20	0.00	0.00	0.00	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.06	0.10	0.10	0.08	0.00	0.00	0.08	0.00	0.10	0.12	0.09	0.69	0.75
	0.00	0.00	0.00	0.42	0.42	0.00	0.43	0.00	0.00	0.00	1.27	2.02	2.00	2.02	0.00	0.00	2.01	0.00	1.97	1.91	1.99	13.93	15.20