Informed Decision for Planning the Public Health Infrastructure in Madhya Pradesh – Multiple Criteria Decision Analysis

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Abstract: **In Madhya Pradesh, the conventional method of supply and demand calculation for a comprehensive primary health care facility in rural areas is population census-based. The study is breaking the conventional method and using population and distance to the nearest public health facility for demand calculation. Location-allocation model of Arc GIS 10 was used for analyses. Currently, about 10, 209 Sub Health Centres are located in rural Madhya Pradesh in 313 developmental blocks. This study highlights the use of Geographic Information System technology for planning comprehensive health centres to optimize access to the rural population. Although the location-allocation methodology has been available for decades, it has been used sparsely by public health professionals. This paper makes an important contribution to the method for planning in resource-limited settings.**

Key words**: network analysis, public healthcare system, infrastructure planning, resource allocation**

I. INTRODUCTION

Madhya Pradesh has a population of 7.2 crores as per census 2011. The population of Madhya Pradesh has grown from 6 crores in 2001 to 7.2 crore in 2011, an increase of almost 20 percent in a decade. According to population projections for India and the States 2001-2026 (Office of RGI), the population of Madhya Pradesh is expected to reach 8.8 crores by the year 2026. The changing population and societal behavior are intensifying the pressures on health systems and demanding more healthcare service centers. The National Health Policy 2017 highlights issues related to Infrastructure and Human Resources/Skill Gaps. According to the government of Madhya Pradesh official records, there are 10,204 Sub Health Centers, 1,205 Primary Health Centers, 330 Community Health Centers, 86 Civil Hospitals and 51 Districts Hospitals providing health care in the state.

An attempt has been made by the Department of Health and Family Welfare, Madhya Pradesh to determine the prevailing gaps in Sub Health Centers in the state. At the same time, various public health facilities require up-gradation from the current facility type. The Department of Health has requested State Health Resource Centre at Atal Bihari Vajpayee Institute of Good Governance and Policy Analysis to support in identification and validation of public health facilities through a scientific data-driven approach.

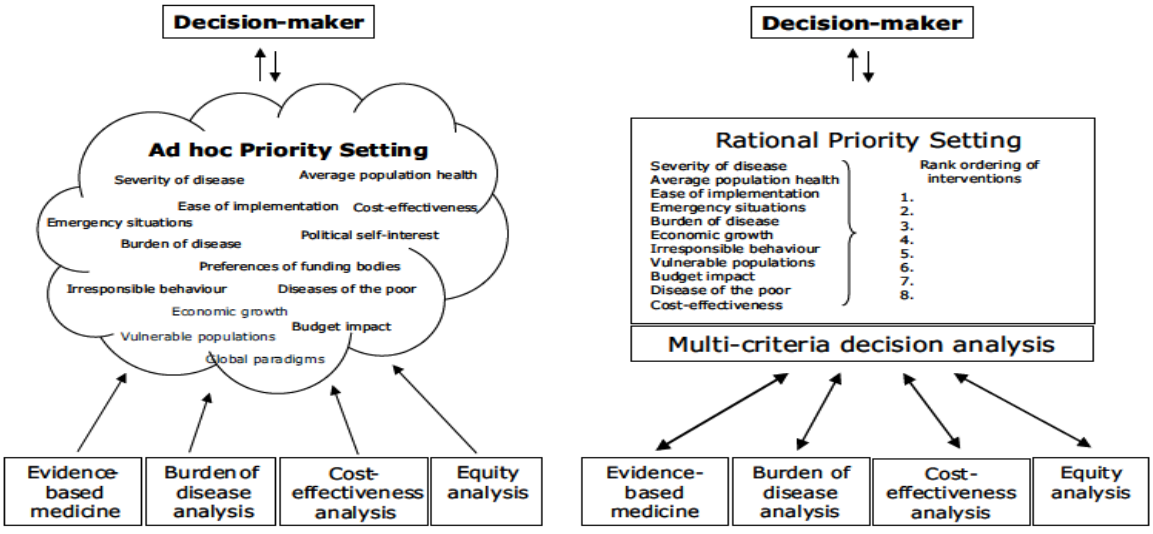


Figure 1: Ad hoc priority setting and rational priority setting

Source: adopted from Rob Baltussen, 2006

The infrastructure site decision influences and shapes the overall healthcare network within an area. It is also a delicate decision for the local population who are traditionally consulted via a mailed questionnaire. However, this method is not the most rational or transparent way to optimization of our research objectives and thus other methods are needed to improve the site location decision-making process (Dehe, et al., 2011). Healthcare organizations are becoming increasingly accountable to the local population (DoH, 2010) and modeling techniques such as location-allocation models and Geographic Information Systems (GIS) have been promoted to optimize site locations (Luis, 2004).

Infrastructure priority setting in the public health sector is often carried out on an ad-hoc basis and resources are not used to their optimal extent. The underlying problem is that apart from multiple criteria being used, decision-making itself is a complex process. Suitable interventions may be chosen to maximize general population health, reduce health inequalities of disadvantaged or vulnerable groups, and/or respond to life-threatening situations, all with respect to practical and budgetary constraints (Rob Baltussen 2006).

The literature shows a worldwide use of MDCA in the healthcare sector. Its use and applications remain varied, to support both clinical (Miot, et al., 2012; Youngkong, et al., 2012) and managerial (Dey et al., 2008; Grigoroudis et al., 2012) decision-making during complex problem-solving.

In order to identify the appropriate locations for the establishment of new sub-health centers and to carry out the validation procedure for the up-gradation of public health facilities, Multiple Criteria Decision Analysis (MCDA) using the Geographic Information System (GIS) based location-allocation analysis model has been chosen. The Evidential Reasoning (ER) technique was also adopted to set the priority of public health facilitates selected for up-gradation.

The location-allocation-based network analysis allows for assessing whether all the demands related to demography, road condition, and infrastructure are covered at the facility level. GIS is a powerful tool designed for spatial analysis which provided functionality to capture, store, question, analyze, display and materialize geographic information. As such, it has an enormous impact on the spatial decision-making process. Recent development in the field of decision-making has led to dramatic improvements in the capabilities of GIS in location-based analysis. These developments are evaluated through analysis of attribute data especially procedures of multi-criteria and multi-objective location-allocation based network analysis in GIS.

II. METHOD AND MATERIAL

Two models have been used – initially, the GIS-based location-allocation Model was used for block-level location identification of new SHC. The Geographic Information System (GIS) based location-allocation analysis was used to determine the candidate locations (best suitable locations) for future facilities (No. estimated according to current population demand) after performing multiple iterations of network analysis in ArcMap 10.5.1 format. Thereafter, the Evidential Reasoning (ER) Model was used for setting the priority of PHC, CHC and Maternity wing selected for up-gradation. The GIS-based network analysis has been carried out in Arc Map 10.5.1 version. Whereas, quantitative analysis based on the evidential reasoning model has been performed in Ms Excel.

Data sources

(1) the census population in 2011 was obtained to calculate the coverage of public health facilities. (2) the Pradhan Mantri Gram Sadak Yojana (PMGSY) and ISRO satellite images ortho-rectified - Natural Color Composite Merge Product (Cartosat-1 + RS2 L4MX) of 2.5 m resolution were used for the road network in the state. (3) the GIS coordinators of Public Health Facilities total of 9,211 health points located in 313 blocks were used in the analysis. The summary of the dataset used in the study is shown in the table below:

Data	Source	format
Population	Census 2011	xls
Road network	PMGSY 2018; ISO Image	.shp
Public Health Facility	GoMP	.shp

Data validation

In order to confirm the data accuracy, a real-time data validation platform was developed. The block-level health officials accessed the online portal and verified the location (geographical locations) of existing public health facilities at the Block level. The portal developed was fully protected and secured so that no one could tamper with the data received.

Base map preparation

Layers pertaining to administrative boundaries and road network of the entire Madhya Pradesh state were modified initially thereafter, a digital map of public health facilities was composed and the population in all the villages across the state was incorporated into the map. The following procedure was adopted for determining the appropriate locations for establishing the new Sub Health Centres.

i. The road networks of 313 blocks were digitized using high resolution, ortho-rectified, Natural Color Composite Merge Product (Cartosat-1+RS2L4MX) of 2.5 m resolution.
ii. Topological rules were applied to make the road network data error-free. Since road networks are the pillars of network analysis, hence error-free data is mandatory.
iii. The list of health facilities, habitation points and road networks were, first of all, plotted along with the block boundary.
iv. Settings used in the analysis were - impedance, travel from demand to the facility, allowing U-turns at junctions and the output shape type to a straight line.

In order to do the final analysis, the problem type has been selected as 'maximize coverage' with Impedance cutoff (drive time) kept at 20/25/30 minutes. The analysis was thereafter executed and the habitation served by each sub-health center was identified.

v. The candidate locations (best suitable village) were loaded after performing the initial network analysis. After multiple iterations, the final possible location (village) was identified and displayed on the map.

vi. Field visits of randomly selected locations were made to ensure the ground reality verify physically.

Evidential Reasoning analysis

In this method, first, the expected option is assigned a numerical score reflecting the strength of the preference scale for each option for each criterion. More preferred options score higher on the scale, and less preferred options score lower. Considering the significance of the health care service delivery in the state, the following key indicators were selected as criteria:

Table 1: Indicator wise criteria for priority setting and weightage

S. No.	Indicator	For Sub Health Centre/Primary Health Centre/ Community Health Centre/Maternity Wing
Criteria for setting priority with weights		
1	Population (30)	For SHC - higher weight with high population Tribal Block - (i) 3000 (ii) 2000 (iii) 1000 General Block - (i) 5000 (ii) 3500 (iii) 2000
2	Distance in KM (30)	Village away from existing health facility SHC: min 20 min drive time from nearby PHC (15 Min drive time for tribal) PHC: min 20 min drive time from nearby PHC (15 Min drive time for tribal) CHC: min 30 min drive time from CHC (20 min drive time for tribal)
3	IPD/OPD records (10)	PHC/CHC - higher weight with available record
4	Child Immunization (10)	PHC/CHC - higher weight with higher record
5	Number of deliveries (10)	Maternity Wing (PHC/CHC) – higher weight with higher record
6	Nature of block (10)	Tribal block weight assigned General block no weight assigned

It was assumed, that the criteria are independent of each other. The final score is calculated through the multiplication of the value score on each criterion by the weight of that criterion and then adding all those weighted scores together. The procedure to develop a score is defined in the flow diagram below:

Figure 2: Flow diagram for setting up priority exercise

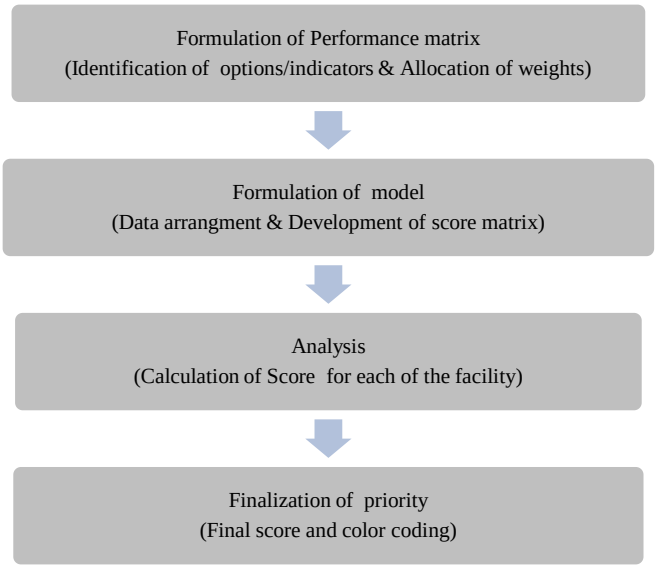


Table 2: Priority setting based on the final score of public health facility

S. No.	Facility	Final Score	
		Priority I	Priority II
1	New SHC	Final score 50 or more	Final score less than 50
2	SHC to PHC	Final score 50 or more	Final score less than 50
3	PHC to CHC	Final score 50 or more	Final score less than 50

III. RESULT

The results of the analysis highlight the demand for new health facilities in the state. The tables related to existing and proposed public health facilities in respective blocks is shown below including new establishment based on multiple criteria.

Potential locations for new SHCs

The table below shows the requirement for an additional 1,628 SHCs in the state of Madhya Pradesh. Out of a total of 313 blocks in the state, the analysis was performed on 266 blocks that need the addition of at least one SHC. However, the requirement for a new SHC varies across blocks. A majority of blocks have shown a requirement for 1 to 5 new SHC.

Table 3: No of demand villages identifying for the location of new Sub Health centres

	Total	Analysis Performed	Existing no. of SHCs	Proposed no. of SHCs
District	51	49	9,211	1,628
Block	313	266	9,211	1,628
Tribal Block	89	67	2,387	346
General Block	224	199	6,824	1,282

Table 3 represents the district tribal and general blocks-wise existing and proposed SHCs. It is important to note that an additional 346 new SHCs are needed in 67 tribal blocks of

Madhya Pradesh. However, more than a thousand SHCs are needed in 199 blocks under the general population category.

Table 4: Average distance (in KM) before and after analysis

	No of Blocks	Average distance (KM)	
		Before analysis	After analysis
Total	266	3.169	2.851
Tribal	67	3.21	2.925
General	199	3.147	2.824

Table 4 represents the improvement in access by the population to reach the nearest SHC. It can be observed in the above table that the average distance to reach a SHCs has decreased by 0.72 km in different tribal blocks and 0.68 km in general blocks. The rural population usually suffers the most in terms of access to health facilities. Improved accessibility would encourage villagers to avail of primary health care services from the nearest public health facility.

Validation and Priority setting of public health facilities

The purpose of this analysis was to set the priority of selected public health facilities identified for up-gradation by the district-based field exercise. The field-based exercise included the existing SHCs with an increased population around them and those with changing demand that needed to have an up-gradation. Some needed a 'maternity wing' to be added to them, whereas, others were supposed to be upgraded a level up. For example, in Rural areas the SHC was to be upgraded to a Primary health center. In order to validate the suggested public health facilities initially, GIS-based location-allocation analysis was performed to define the score. Thereafter, multiple criteria decision analysis was done to determine the final score for each of the selected facility. The final score was further classified as Priority I (scores more than 50) and Priority II (scores less than 50). Table 5 presents a summary of 667 public health facilities which need to be upgraded in 49 districts according to final score set for the priority. The summary findings are given in the table below:

Table 5: No of facility according to priority

No of Districts	No of Block	Facility Type	No of facility	Priority I	Priority II
8	17	Maternity Wing	23	23	-
38	98	Sub Health Centre	278	239	39
46	155	Primary Health Centre	291	222	69
33	67	Community Health Centre	73	60	13
Total			665	544	121

In 665 public health facilities, special request for 18 locations for establishing new sub health centers, upgradation request for 3 primary health centers and 17 community health centers were received during the analysis period. In order to maintain the scientific procedure, the same validation exercise has been adopted for these special requested public health facilities.

Considering the importance of suggested maternity wings from district office and due to incomplete data, 23 maternity wings were classified as priority I. However, the facility type of these maternity wings needs confirmation.

Table 6: Number of health facilities according to priority in tribal and general areas

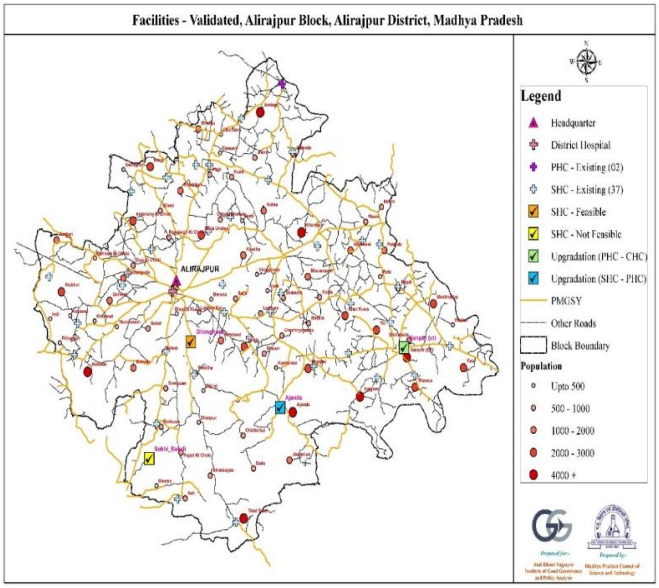
Area	No of Block	Facility Type	No of facility	Priority I	Priority II
Tribal	7	Maternity Wing	12	12	-
	36	Sub Health Center	99	77	22
	49	Primary Health Center	94	76	18
	17	Community Health Center	20	15	5
Non-Tribal	10	Maternity Wing	11	11	
	62	Sub Health Center	179	162	17
	107	Primary Health Center	197	146	51
	50	Community Health Center	53	45	8
Total	17	Maternity Wing	23	23	
	98	Sub Health Center	278	239	39
	155	Primary Health Center	291	222	69
	67	Community Health Center	73	60	13

Table 6 describes a detailed picture of public health facilities according to priority setting in tribal and general blocks in Madhya Pradesh. A total of 278 sub-health centers have been suggested for establishing the new SHCs in 98 blocks in the State. Out of which 239 villages need immediate action whereas, 39 locations may be established in the second phase. It is significant to note that in tribal blocks out of total 99 suggested locations for new sub-health centers, 77 (75%) need immediate action. In the case of maternity wing, all the suggested centers were categories as urgent requirement-hence, no priority was set.

Mapping

The GIS map of each of the blocks was designed to understand the complete picture of the block including existing public health facilities, road connectivity, proposed SHC, and facilities recommended for up-gradation. Maps have been a crucial element in the report providing us with spatial grounding and evidence. They have also helped in the contextualization of data, specifically for locating the existing health systems, and further proposing the new SHCs. The key component of a map that is so important for this is scale, as by mapping to scale a study area demographic information can be localized and expressed in terms of distance relationships.

Figure 3: Block map considering demand location and upgraded health facilities



IV. DISCUSSION

Utilizing a step-wise process, the identification of demand villages for the location of new sub-health centres in 266 Blocks of 49 districts in the state of Madhya Pradesh was done based on GIS network analysis. In this analysis, it was found that while in some blocks, a large number of Sub health centres needed to be established, other blocks had sufficient no. of sub health centres present. Also, the study identifies potential demand villages in each block. This comprehensive list of demand villages along with their population ranking allows Government officials to choose the best possible location for new sub-centre after considering the local demands.

It is important to note that the demand for 278 new SHC has been suggested by the department with the support of the district officials. Out of these 278 SHCs, 239 need to be established on a priority basis. Interestingly, not all districts have a high need, indicating that the increased needs of the population have already been addressed by the government by setting up of new SHC previously. However, with the maximum requirement for new SHCs, districts, like Rajgarh and Morena need special attention. Other districts which also need attention are Narsinghpur, Ratlam, Dhar and Barwani. It is also important to look at the validation of public health facilities selected for up-gradation that might need high attention due to high demand. For example, blocks like Rama (Jhabua) and Basoda (Vidisha) and Kailaras (Morena) have a high requirement of all - maternity wing, new SHC, PHC and CHC.

In stage one of this project, we developed the criteria for locating new SHCs and suggest appropriate locations for establishing them using the GIS-based network technique. In stage two, the validation exercise for selected public health facilities was carried out using the GIS technique. Subsequently, the evidential reasoning model was applied for setting the priority 1 and 2 of these selected health facilities. However, there is no direct connection between results generated in stages 1 and 2.

Policy options and implications

This report provides the use of health information for evidence-based informed policy decision-making and even suggests an example of how the use of scientific tools and procedures enable the provision of better-quality information. Based on these findings, a number of options are set out for different stakeholder groups like health information producers, knowledge partners and end-users of health information e.g., policy-makers.

Health information producers:

- ensuring that the health information produced meets the needs of, and is relevant to, the end-users by engaging with them on a continuous basis;
- establishing trusted partnerships and increasing the prospects of reliability and use of health information being considered;

Knowledge partners:

- establishing relationships with and acting as a link between producers and users of health information to build a value chain and bring health information into practical use;
- adding value to health information by using scientific tools for informed decision-making.

Health information users:

- informing information providers to identify and fulfill information gaps;
- Ensure the best available evidence is used to support the choice of policy options.

V. CONCLUSION

The study here shows the work undertaken using spatial and non-spatial data for the selection of villages and also for establishing the new Sub Health Centers based on the Geographical Information System (GIS) based Location Allocation model. However, it is important to first develop a criterion for the identification of new locations and also map the existing health facilities. Both above-mentioned criteria have been used to identify new locations for Sub health centers based on location-allocation models of network analysis conducted using the GIS platform. Distance, population, and access (road network) are the factors considered as part of a mandatory criterion for the selection of potential candidate villages while doing GIS analysis.

In this study, we have found the potential candidate villages for 266 blocks of 49 districts in the state of Madhya Pradesh. Giving options for the location of new facilities allows the Government to choose the best possible location based on

local conditions/factors. Identification of ideal locations for new health facilities using this tool would improve access to healthcare for the rural population and will prevent clustering of health facilities. In this way, the maximum population as per IPHC-NHM norms can be covered.

The evidential reasoning method produced priority criteria for the up-gradation of public health facilities in the state of Madhya Pradesh. The analysis conducted in 155 blocks in 46 districts shows that the priority of location needs immediate attention. This method incorporates the nature of the block including tribal and remote areas, population, and access. Importantly, the findings are the best amalgamation of data and field-based recommendations.

To conclude, this study confirms the requirement for additional sub-centers and up-gradation of public health facilities in the state. The study also suggests the potential demand by villages for locating new sub-centers in order to improve access to health care. The priority status would certainly help in allocating the resources to inappropriate locations for improving the access to healthcare for the rural population.

Limitations

The study is limited to the block and district boundaries available from Pradhan Mantri Gram Sadak Yojana (PMGSY) data only. The availability of sub-health centers (supply) for population (demand) for primary health care services was calculated using secondary data from different sources such as Census, PMGSY and cross-sectional health facility survey conducted by the department of health and family welfare Madhya Pradesh.

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