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Assessing the performance of primary health centres in Meghalaya: An automatic linear modelling

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Abstract

The spatial distribution and performance of Primary Health Centres (PHCs) play a vital role in shaping health care delivery in Meghalaya, a predominantly rural, hilly state in northeastern India characterized by scattered settlements and challenging terrain. This study investigates disparities in PHC performance across districts, highlighting critical gaps in equitable health care access. Meghalaya's topography, with elevations ranging from 150 to over 1,950 meters, creates significant logistical and infrastructural barriers to service delivery. Using secondary data from government sources (Statistical Handbook, 2023), the study applies Z-score analysis and Automatic Linear Modelling (ALM) via SPSS to examine the relationships between PHC performance (dependent variable) and key health system variables. The ALM approach effectively identifies significant predictors of PHC efficiency and constructs a robust explanatory model. Findings reveal that East Khasi Hills, West Jaintia Hills, and West Garo Hills districts rank highest in health care delivery efficiency, while other districts lag, underscoring spatial inequities. The study provides strategic recommendations to strengthen PHC infrastructure, optimise resource allocation, and improve health outcomes for underserved and remote populations in Meghalaya.

Keywords: PHC; Health Care Delivery; Spatial Inequity; Z-Score Analysis; Automatic Linear Modelling (ALM); Rural Health; Health -Performance

1. Introduction

Health is a common theme in all nations of the world. Health has evolved over the centuries from a concept of concern for an individual to a worldwide social goal and encompasses the whole quality of life (1,2,3,4). Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (5). Effective primary health care relies on seamless coordination between various healthcare providers and services (6,7,8,9). Over the decades, the concept of health has evolved from a narrow focus on individual disease to a broader social goal emphasizing population well-being and equity.(10,11,12,13) The Alma-Ata Declaration framed health as a fundamental human right achievable through primary health care (PHC), promoting community participation and intersectoral

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action (14). This vision aligns with the Sustainable Development Goals, which embed health within social, economic, and environmental priorities (15,16,17). PHC remains central to achieving universal health coverage, requiring equitable access, appropriate technology, and effective coordination among community health workers, PHCs, and referral services (18,19,20,21). In rural and hilly regions like Meghalaya, health access is shaped by poverty, geography, and fragile infrastructure. Poverty limits people's ability to seek care due to transport costs, wage loss, and out-of-pocket expenses, often leading them to delay treatment or depend on informal providers (22,23,24,25). Social determinants such as poor housing, inadequate sanitation, and low education compound these challenges (26,27,28).Nevertheless, studies reveal persistent gaps in staffing, supply chains, and referral linkages, particularly in remote and hilly terrains, where geographic isolation and difficult logistics hinder service delivery (29,30,31,32).Telemedicine pilots offer promise in bridging these gaps, but their scalability and long-term sustainability in such settings require further evaluation (33,34,35). Addressing these complex issues demands a comprehensive approach that combines infrastructure strengthening, human resource strategies, community engagement, and research tailored to the unique contexts of regions like Meghalaya.The main reason for the lack of health consciousness of the people, especially in rural areas, is the burden of poverty that has set a major hurdle for getting access to health care (36,37,38).The primary health centre is essential health care made universally accessible to individuals and families in the community by providing essential drugs and medicines.(39,40,41) The community services offered by the PHC are prevention, delivery system, and control of endemic diseases and environmental health programmes (42,43,44,45).Health is influenced by several factors such as adequate food, housing, basic sanitation, healthy lifestyles, protection against environmental hazards, and communicable diseases (46,47,48).

Objectives

The main objectives of this paper are given as follows: -

- To analyse the spatial distribution of PHC in Meghalaya.
- To analysehealth care variables to constructALM

1.1. Study Area

Meghalaya, 'the Abode of Clouds' is one of the North Eastern states of India.It lies between latitudes 25°02' and 26°07' N and longitudes 89°49'and 92°50'E, with a geographical area of 22,429 sq. Km and an elevation range from 60m to 1961m ASL (Laitkor Peak at 1961m is the highest). (Fig.1) The climate is of monsoon type with distinct warm-wet and cold-dry periods. Cherrapunji and Mawsynram, located in the southern part, are the rainiest spots in the world.

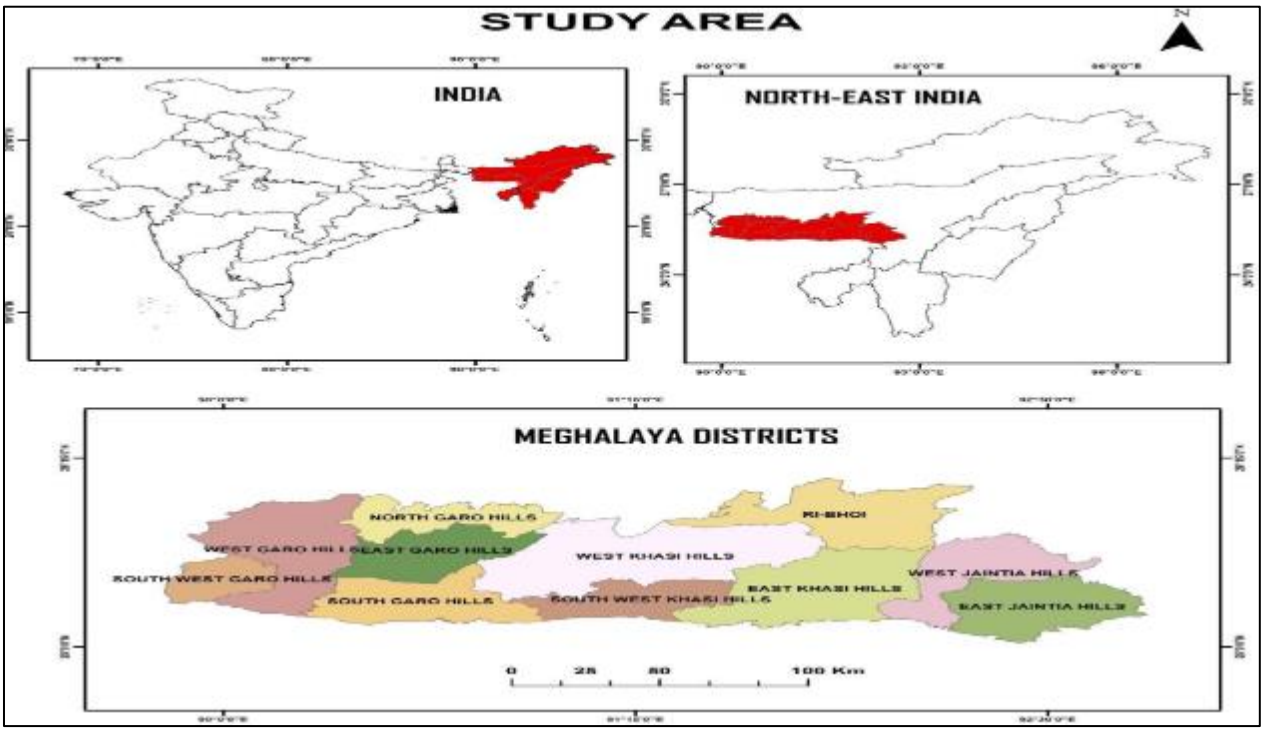

Figure 1 Study Area Map of Meghalaya

2. Data Source and Methodology

2.1. Sources of Data

The data collected for the present study are mainly based on the information provided by the government departments which is through the Statistical Handbook of 2023issued by the Directorate of Economics and Statistics Government of Meghalaya, the collected information who are availing these health care services and secondary which are gathered from various sources.

2.2. Secondary Data

The demographic and social variables for Meghalaya were obtained from the statistical handbook on Meghalaya for the year 2023 from the Directorate of Economics and Statistics, Shillong. The other statistical data were collected from respective offices. The study area maps and related information were obtained from the statistical handbook for Meghalaya 2023.

2.3. Techniques Used

$$z = \frac{x - \mu}{\sigma}$$

A Z-score is a statistical measurement of a score's relationship to the mean in a group of scores (49,50,51). A Z-score of 0 means the score is the same as the mean. A Z-score can be positive or negative, indicating whether it is above or below the mean and by how many standard deviations. A 'Z' score is a statistical measurement of a score's relationship to the mean in a group of scores(52,53,54).A 'Z' score can also be positive or negative, indicating whether it is above or below the mean and standard deviation. Z' score can also be explained as in addition of showing a score's relationship to the mean. (55,56,57).The 'Z' score shows a statistical data set. One real-life application of the 'Z' score is a usability testing score that is arrived at by calculating the difference so derived is then divided by the standard deviation of the population

The relationships and the interdependent nature of different variables are analysed using the ALM, capable of explaining the relationships of one dependent variable (PHC) with all other variables. It is derived by using SPSS (Statistical Package for Social Science).

3. Results

The spatial and statistical analysis of the health care delivery system in Meghalaya reveals significant disparities in the distribution and availability of health infrastructure and human resources across the eleven districts of the state. The results derived using Z score analysis (through SPSS 14.0) and mapped using QGIS demonstrate the following key findings: According to Z score analysis, the region may be classified into 4 categories, such as very high representing values of (more than 0.50), High (0- 0.50) moderate (-0.50- 0) and low (less than -0.50).

3.1. Distribution of Primary Health Centres (PHCs)

The spatial analysis of PHCs highlights that East Khasi Hills district stands out with the highest Z score (2.55), indicating a very high concentration of PHCs (Fig. 2). This can be attributed to the district's urbanisation, higher population density, and presence of the state capital, Shillong. In contrast, South West Khasi Hills shows a very low Z score (-1.06), reflecting the lowest number of PHCs due to its recent bifurcation from West Khasi Hills and an underdeveloped health infrastructure.In contrast, districts with rugged terrain and sparse population like South West Khasi Hills, face logistical challenges, resulting in fewer health centres and limited accessibility to healthcare services.

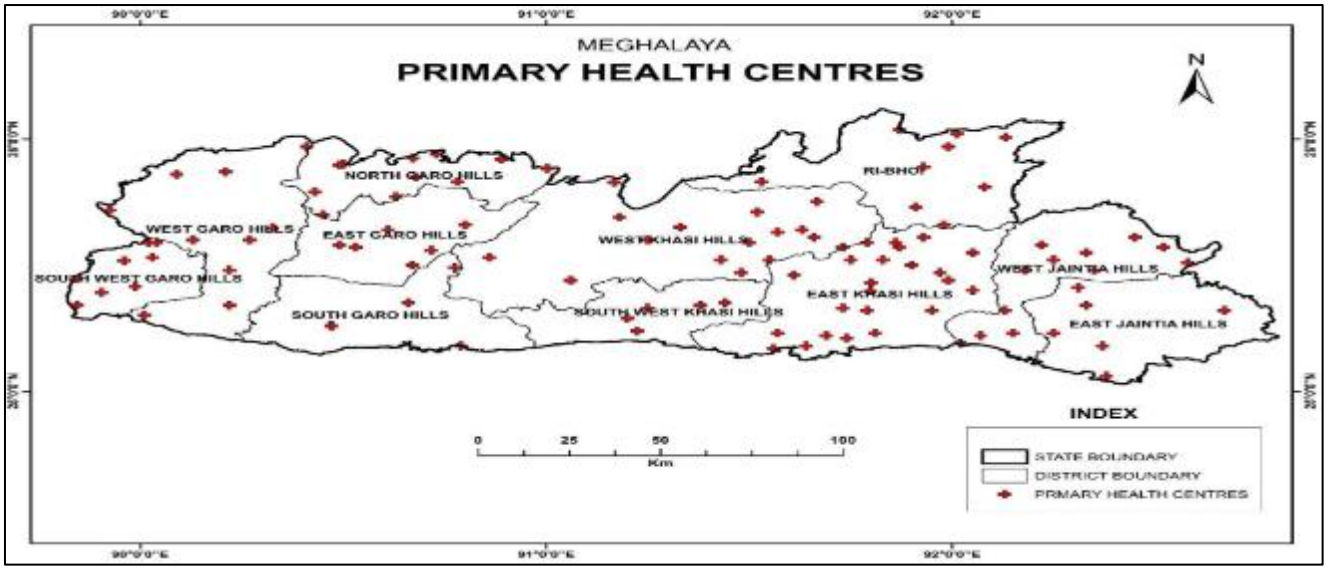

Figure 2 Spatial Distribution of PHCs Meghalaya

3.2. Availability of Doctors

A similar trend is seen in the distribution of doctors. East Khasi Hills again scores the highest (2.42), supported by the presence of specialised medical facilities and higher patient inflow from nearby districts.West Garo Hills (1.33) follows due to its regional prominence. East Jaintia Hills (-0.84) has the least number of doctors, reflecting infrastructural challenges and limited health centres (Fig.3).

3.3. Availability of Pharmacists

The concentration of pharmacists correlates with the number of health centres. East Khasi Hills scores the highest (2.73), indicating an adequate number of pharmacists serving the population. South West Khasi Hills (-0.85) again records the lowest, reinforcing the district's underserved status (Fig.4).

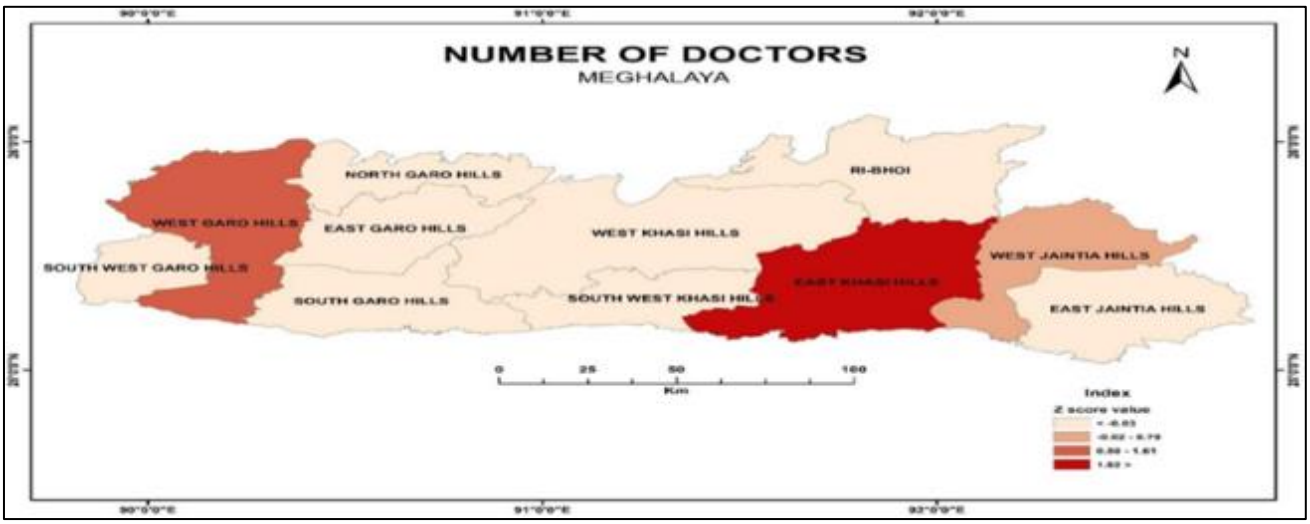

Figure 3 Spatial Distribution of Doctors in Meghalaya

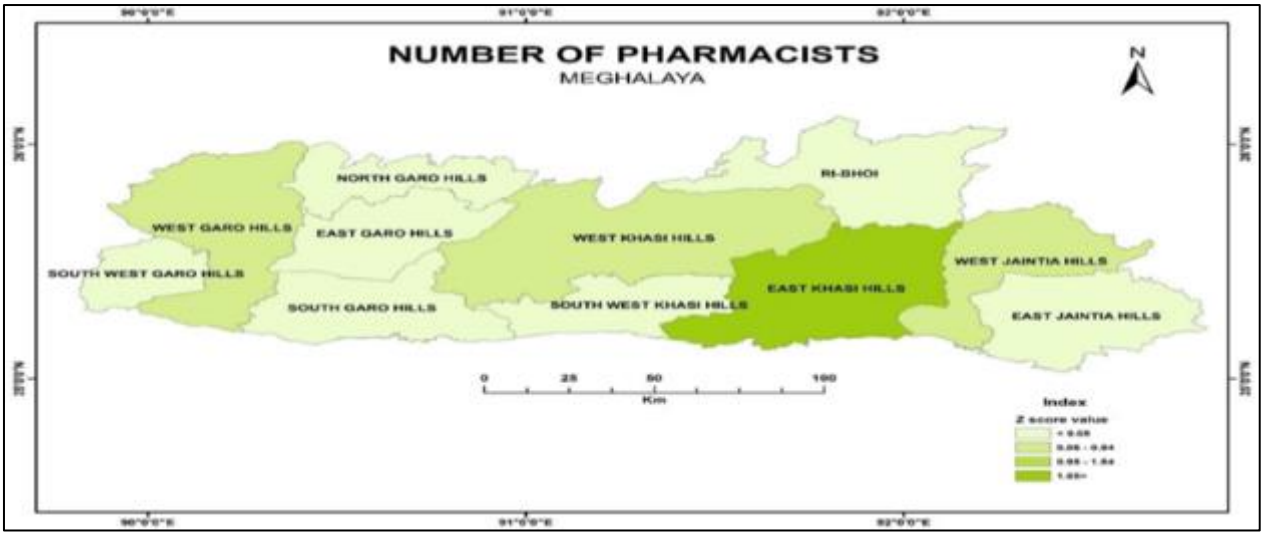

Figure 4 Spatial Distribution of Pharmacists in Meghalaya

4. Discussion

The health care delivery system in Meghalaya presents a complex picture of progress and challenges. The spatial analysis using Z scores has revealed substantial disparities in the distribution and accessibility of primary healthcare infrastructure across the eleven districts of the state. The rugged terrain and dispersed rural population play a significant role in shaping the healthcare landscape (54,55,56).Districts such as East Khasi Hills, West Garo Hills, and West Jaintia Hills consistently perform better in terms of the number of PHCs, availability of doctors, pharmacists, and overall healthcare efficiency. These districts benefit from higher population density, better road connectivity, urbanisation, and proximity to administrative centres. East Khasi Hills, in particular, houses the state capital, Shillong, and leads in nearly all healthcare parameters due to its advanced infrastructure and concentration of medical manpower.

Table 1 Z-score value of the Health Care Delivery System in Meghalaya

Districts	1. PHC	2. Sub-Centre	3. Community	4. Doctor	5. Nurses	6. Lab.Tec	7.Pharmacists	8. Vaccinator	9. Visitor
EastJaintiaHills	-0.42	-0.34	-0.48	-0.54	-0.51	-0.42	-0.43	-0.57	-0.24
WestJaintiaHills	-0.22	-0.24	-0.20	-0.27	-0.33	-0.21	-0.22	-0.22	0.10
RiBhoi	-0.36	-0.34	-0.20	-0.32	-0.38	-0.27	-0.38	-0.50	-0.45
EastKhasiHills	0.21	-0.03	0.34	0.51	0.92	0.28	0.42	0.51	0.27
WestKhasiHills	-0.12	-0.24	-0.34	-0.29	-0.31	-0.19	-0.17	-0.22	-0.37
SouthWestKhasiHills	-0.49	-0.47	-0.34	-0.51	-0.52	-0.50	-0.50	-0.50	-0.45
NorthGaroHills	-0.26	-0.22	-0.48	-0.48	-0.49	-0.40	-0.38	-0.43	-0.32
East GaroHills	-0.39	-0.37	-0.48	-0.37	-0.38	-0.38	-0.39	-0.43	-0.49
WestGaroHills	-0.32	-0.08	0.07	0.15	-0.12	-0.17	-0.19	-0.12	-0.32
SouthGaroHills	-0.42	-0.41	-0.48	-0.44	-0.42	-0.46	-0.43	-0.29	-0.41
SouthWestGaroHills	-0.32	-0.40	-0.48	-0.45	-0.40	-0.40	-0.43	-0.26	-0.41
Total	3.12	3.15	3.07	3.02	2.93	3.11	3.08	3.04	3.09

Table 1 Z-score value of the Health Care Delivery System in Meghalaya (Cont…)

10.Indoor patients	11.Outdoor Patients	12.No of Beds	13.Immunization	14.DPT%	15.TD Booster	16.A.N.M	17.No.Habitations	18.Population	19.Area SqKm
-0.34	-0.46	-0.41	-0.41	-0.28	-0.18	-0.37	-0.20	-0.45	-0.30
0.06	-0.14	-0.29	-0.17	-0.30	-0.22	-0.23	-0.49	-0.26	-0.18
-0.20	-0.02	-0.33	-0.31	-0.28	-0.27	-0.40	-0.30	-0.28	-0.12
0.13	0.61	0.49	0.21	-0.32	-0.33	0.23	0.22	0.45	-0.14
-0.31	-0.23	-0.19	-0.13	-0.28	-0.12	-0.30	-0.42	-0.39	-0.37
-0.45	-0.47	-0.51	-0.47	-0.26	-0.18	-0.53	-0.54	-0.48	-0.42
-0.44	-0.51	-0.47	-0.41	-0.32	-0.43	-0.26	-0.25	-0.39	-0.36
-0.37	-0.42	-0.40	-0.43	-0.32	-0.29	-0.35	-0.57	-0.42	-0.11
-0.38	-0.44	-0.15	-0.07	-0.26	-0.39	-0.15	-0.05	-0.01	-0.28
-0.44	-0.47	-0.41	-0.48	-0.32	-0.38	-0.42	-0.46	-0.43	-0.47
-0.37	-0.46	-0.38	-0.42	-0.23	-0.37	-0.34	-0.02	-0.38	-0.41
3.12	3.01	3.06	3.11	3.17	3.16	3.12	3.08	3.06	3.15

5. Automatic liner modelling (ALM)

Automatic linear modelling (ALM) is preferred for analysing data sets due to its simplicity in analysing data and interpreting the results, and its ability to present results visually and provide more detailed information, especially when studying large, complex data sets.

In this analysis, the given variable groups are no of PHC in each district of Meghalaya, Sub-PHC, Number of doctors, Nurse, Pharmacists,lab-technician, vaccinator, number of patients both indoor and outdoor, immunization, types of Booster does, area of Population and sub-variables are each group can be converted to standardized the data in the form of Z score value. (Table 1).The respondents of the variable denoted as a dependent variable, with related Z score of each variable, are independent variables.

It will be beneficial to use Automatic linear modelling, especially in analysing massive and complex data sets, to investigate the relationship between one continuous dependent variable and multiple predictors and determine the factors that affect the response or target variable. At the same time, it will also be possible to evaluate the effect of each predictor with a more detailed response. One of the other important features of the ALM is that since it presents the results graphically, it automatically prepares the data preparation of the given Z-score value. In the process of building an ALM, the following basic steps are created based on the list. Initially preparation of data focused on finding the Z-score value rather than the standard Z-score value.

There are 19 Variables chosen for analysis in the Automatic Liner model. The variables are health manpower,number of PHCs, and Sub PHCs location in each district, health delivery system, utilisation of health care of the population, total population covered,serving area, etc. The number of PHC is considered about dependent variable, and all other variables are independent variables.

Predicted by observed variables are chosen based on the reliability ofPHC function(Fig.5).In the analysis there are two important predicted variables are identified, viz, Pharmacist and number of doctors. (Fig.6) In this two variables notably contributed to the service of PHC in Meghalaya.In these two predicted variables, Doctors, Pharmacist are the PHC function and its service significance.

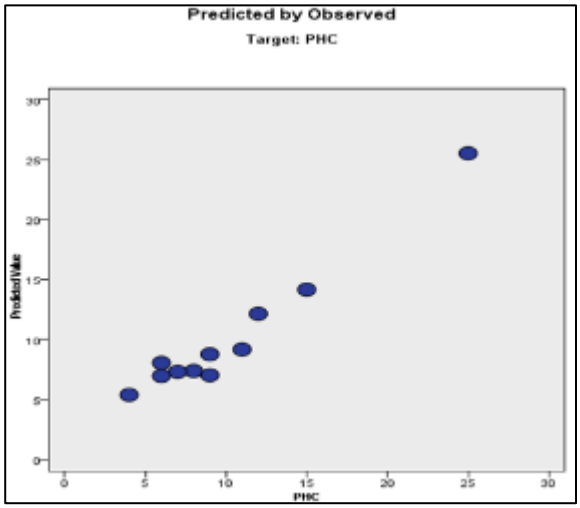

Figure 5 Predicted by observed variables

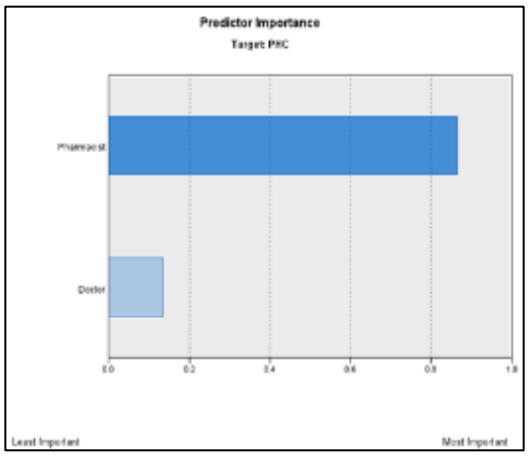

Figure 6 Identified Positive and Negative variables

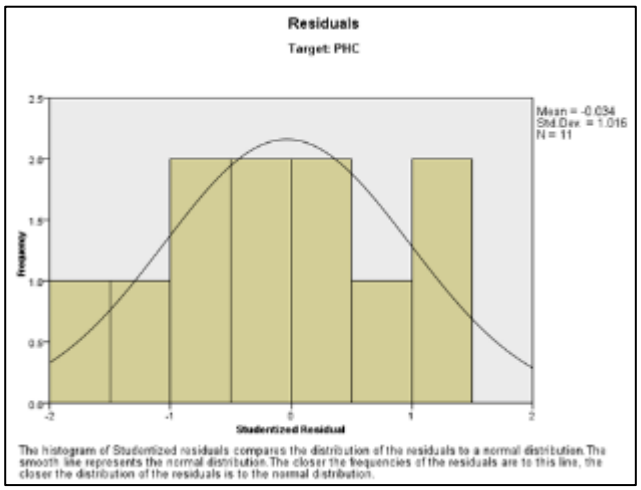

Figure 7 Residuals frequency

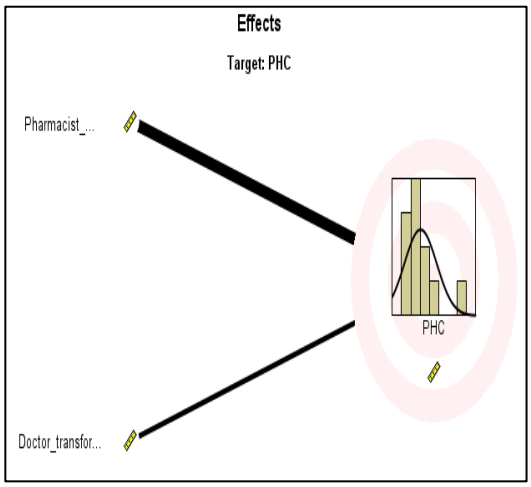

Figure 8 Effects of the Predicted Variable

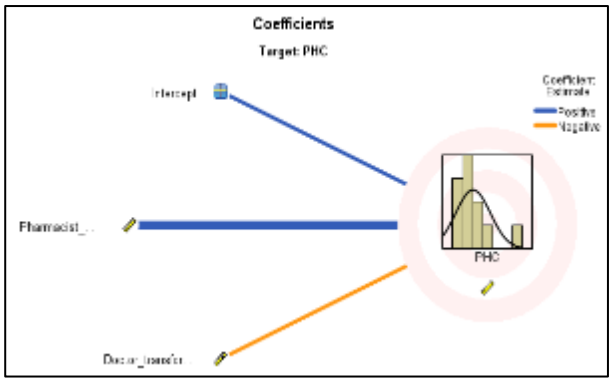

Figure 9 Coefficients Between the Predicted Variables

Outliers

Target: PHC

R...	PHC	Cook's Distance
4	25	1.542

Records with large Cook's distance values are highly influential in the model computations. Such records may distort the model accuracy.

Figure 10 Cook's Distance target variable (PHC)

The histogram of studentized residuals compares the distribution of the residuals to a normal distribution based on the mean of 0.034 and the standard Deviation of 1.016. The closer the frequencies of the residuals are to this line, the closer the distribution of the residuals is to the normal distribution. (Fig. 7)Coefficient estimates of the relationship between the variable of PHC and all other independent variables indicate that increasing the number of pharmacists leads to better performance of the PHCfunction,and neither decreasing the doctor ratio has a negative impact on the PHC (Figs 8,9). Influential in the model computations is related to Cook's distance values.In this analysis are Cook's values are

1.542 in 25 selected PHCs in Meghalaya.So the model construction has accuracy based on Cook's distance. (Fig10)Similarly,show that an increase and positive correlation between the variables are PHC and Pharmacist, is better involvement in the Model (Fig.11). Negative correlation in PHC with Doctor ratio shows negative performance in the health care system (Fig.12)

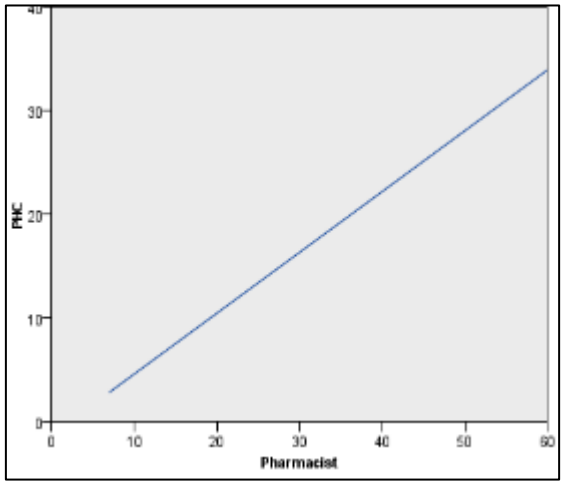

Figure 11 Positive trend of Pharmacist

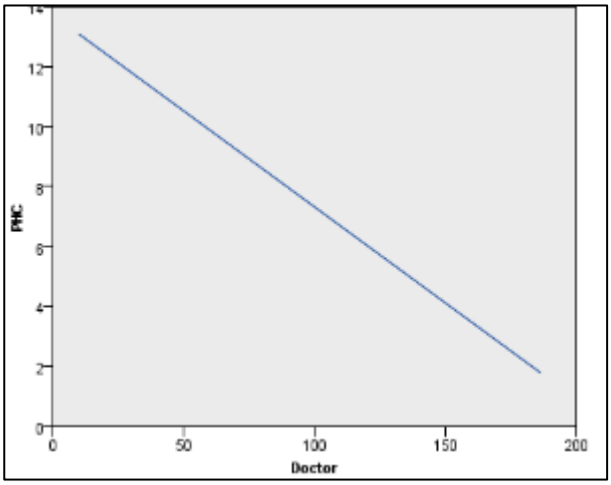

Figure 12 Negative trend of Doctor ratio

Model Building Summary

Target: PHC

		Step	
		1	2
Information Criterion		17.802	13.427
Effect	Pharmacist_transformed	√	√
	Doctor_transformed		√

The model building method is Forward Stepwise using the Information Criterion.
A checkmark means the effect is in the model at this step.

Figure 13 Model building summary of identified variables

Model Summary

Target	PHC
Automatic Data Preparation	On
Model Selection Method	Forward Stepwise
Information Criterion	13.427

The information criterion is used to compare to models. Models with smaller information criterion values fit better.

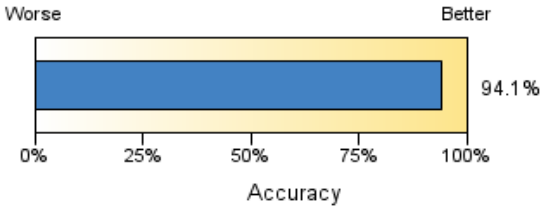

Figure 14 Model fit in the list of variablescontributes to identifying better PHC in Meghalaya

Based on the AL Model Building, the target of the PHC function belongs to the two most important variables are identified (Pharmacist and Doctors.Other variables are related based on the performance of PHC functions (Figure 13). The selected information of variables is used to compare and prepare the Models. Following both independent and dependent variables show a better fit of the model, with an accuracy is 94.1% (Fig. 14). In this aspect Choice of the variables list is are perfect exposure of the ALM approach.ALM can be efficiently used for investigating the relationship between the variables.As a result, it is possible to conclude that the ALM can be efficiently used to identify the level of relationship between the variables in Meghalaya. The study highlights that while PHCs are the backbone of rural healthcare, their uneven spatial distribution has led to inefficiencies in healthcare access. The same trend is observed in the availability of doctors and pharmacists, further widening the healthcare gap. Notably, districts with better

healthcare infrastructure also report higher immunisation coverage and family welfare service delivery, reinforcing the importance of robust local healthcare systems.The efficiency of healthcare delivery, as quantified by Z-score analysis, reveals a direct correlation between the level of urbanisation, infrastructure development, and healthcare outcomes. High-performing districts serve as regional healthcare hubs, often catering to surrounding areas due to the lack of facilities elsewhere.

6. Conclusion

Districts with better connectivity and urban development, like East Khasi Hills and West Garo Hills, demonstrate higher efficiency and better access to healthcare services. Conversely, remote districts struggle with inadequate facilities, insufficient health personnel, and limited service delivery. Investments in road infrastructure, health awareness, and capacity-building of healthcare workers, especially lab technicians and pharmacists, are essential for strengthening the system. To ensure equitable healthcare for all, policies must focus on decentralizing health services, empowering community-level health workers, and integrating modern medical technologies at the primary level. Only through such inclusive and strategic interventions can Meghalaya move towards a more efficient and accessible healthcare system, ultimately improving health outcomes and quality of life for its When it comes to health care efficiency based on Z Score ranking East Khasi Hills, West Jaintia Hills and West Garo Hills has the highest score in terms of being the most efficient district in health care delivery because it hoses the state capital which covers more of an urban area whereby at the same time have a high population and also have better developed health care infrastructure that can cater to needs of the people. The study concludes that Meghalaya's healthcare delivery system, though functioning, is unevenly distributed and influenced by a combination of topographical, demographic, and infrastructural factors. The findings underscore the urgent need for a more balanced distribution of PHCs and healthcare staff, particularly in underserved districts.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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