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HEALTHCARE ACCESSIBILITY IN PRIMARY HEALTH CENTERS OF EAST KHASI HILLS DISTRICT, MEGHALAYA: SPATIAL ANALYTICAL APPROACH

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ABSTRACT

Primary Health Centres (PHCs) form the foundation of rural healthcare delivery by providing essential preventive, curative, maternal and child healthcare services. However, the effectiveness of PHCs depends not only on their availability but also on their spatial distribution, accessibility, infrastructure capacity and ability to meet population demands. The present study assesses the spatial distribution, accessibility and service adequacy of Primary Health Centres in East Khasi Hills District, Meghalaya, using Geographic Information System (GIS), Nearest Neighbour Analysis (NNA), field survey and Z-score statistical techniques. A total of 22 PHCs were mapped to examine their spatial distribution pattern, while five representative PHCs, namely Smit, Jongksha, Wahsherkhmut, Laitryngew and Pomlum, were selected for detailed accessibility and service adequacy assessment. A field survey of 100 respondents was conducted to examine healthcare accessibility characteristics, including travel time, travel distance, mode of transportation and perception of PHC accessibility. The findings indicate that 91% of respondents consider PHCs accessible, while 52% reach healthcare facilities within 15–30 minutes. However, 42% of respondents travel more than 5 km to access PHC services, highlighting geographical accessibility constraints in remote mountainous areas. The Nearest Neighbour Analysis produced an Rn value of 1.2, indicating a random spatial distribution pattern of PHCs across the district. The Z-score analysis based on healthcare indicators such as doctors, ANMs, staff nurses, supporting staff, laboratory technicians, inpatient services, outpatient attendance, population served, villages covered and bed availability reveals significant variations in service adequacy among PHCs. Pomlum PHC demonstrates comparatively better performance, followed by Smit and Jongksha PHCs, whereas Wahsherkhmut and Laitryngew PHCs require improvements in healthcare manpower and infrastructure. The study highlights the importance of GIS-based healthcare planning in identifying spatial inequalities and improving equitable healthcare accessibility and service delivery in mountainous regions.

Keywords: Primary Health Centres, Healthcare Accessibility, Gis, Nearest Neighbour Analysis, Z-Score Analysis, Service Adequacy, Spatial Distribution, Meghalaya, East Khasi Hills District.

1 INTRODUCTION

Access to healthcare services is a fundamental determinant of population health and well-being [1,2,3]. Equitable access to healthcare facilities ensures timely diagnosis, treatment, and prevention of diseases, thereby improving overall health outcomes and quality of life [4,5,6,7]. In developing countries such as India, Primary Health Centres (PHCs) constitute the cornerstone of the rural healthcare delivery system and serve as the first level of contact between the community and the public health sector[8,9,10,11]. PHCs provide essential healthcare services, including maternal and child healthcare, immunization, treatment of common illnesses, health education, and referral services [12,13,14,15]. Healthcare accessibility is a multidimensional concept encompassing availability, geographical accessibility, affordability, accommodation, and acceptability of healthcare services [16,17,18,19]. Among these dimensions, geographical accessibility plays a critical role in determining healthcare utilization, particularly in rural and semi-urban areas where transportation networks, travel distance, and travel time significantly influence healthcare-seeking behaviour [20, 21, 22,23]. Poor accessibility often leads to delayed treatment, reduced utilization of healthcare facilities, and adverse health outcomes [24,25,26,27].Patient satisfaction is widely recognized as an important indicator of healthcare quality and service effectiveness [28,29,30,31]. Previous studies have demonstrated that factors such as healthcare provider behaviour, waiting time, availability of medicines, healthcare infrastructure, and ease of access significantly influence patient satisfaction levels [32,33,34,35]. Satisfied patients are more likely to utilize healthcare services regularly, adhere to medical advice, and maintain positive relationships with healthcare providers [36,37,38,39].

The availability and accessibility of healthcare facilities are important indicators of social and regional development [40,41,42,43]. Primary Health Centres (PHCs) play a crucial role in providing basic healthcare services, particularly to rural populations [44,45,46,47]. However, the effectiveness of these healthcare facilities largely depends on their spatial distribution and accessibility. In areas where healthcare facilities are unevenly distributed, people often experience difficulties in obtaining timely and adequate medical services [48,49,50,51].

Recent advances in Geographic Information Systems (GIS) and spatial analytical techniques have enhanced the ability of researchers and policymakers to evaluate healthcare accessibility and identify spatial inequalities in healthcare service provision [52,53,54,55]. GIS-based methods facilitate the visualization and analysis of healthcare facility distribution, transportation networks, travel patterns, and service catchment areas, thereby supporting evidence-based healthcare planning [56,57,58,59]. Although the district possesses an extensive network of Primary Health Centres, disparities in transportation infrastructure, travel time, and service utilization may influence patient satisfaction and healthcare access across different regions [60]. Understanding these spatial variations is essential for improving healthcare service delivery and ensuring equitable access to healthcare facilities. By employing tools such as correlation analysis, heatmaps, radar charts, K-Means clustering, and the Accessibility–Satisfaction Composite Index (ASCI), the study provides a comprehensive evaluation of healthcare service performance and identifies areas requiring policy intervention and infrastructural improvement [48,49].Against this background, the present study integrates GIS, statistical analysis, and advanced spatial visualization techniques to assess healthcare accessibility and patient satisfaction among PHC users in East Khasi Hills District, Meghalaya.

Objective

The main objective of the study is to assess healthcare accessibility in selected Primary Health Centres of East Khasi Hills District, Meghalaya using GIS and spatial analytical techniques.

Study Area

East Khasi Hills District of Meghalaya was selected as the study area due to its distinct geographical features and variations in healthcare accessibility. The district includes Shillong, the state capital, and is located on the Shillong Plateau between 25°07′ N to 25°41′ N latitudes and 91°21′ E to 92°09′ E longitudes, covering an area of about 2,748 km^2 (Figure 1). It is characterized by rugged hills, valleys, steep slopes, heavy monsoon rainfall, and diverse natural vegetation. According to the Census of India

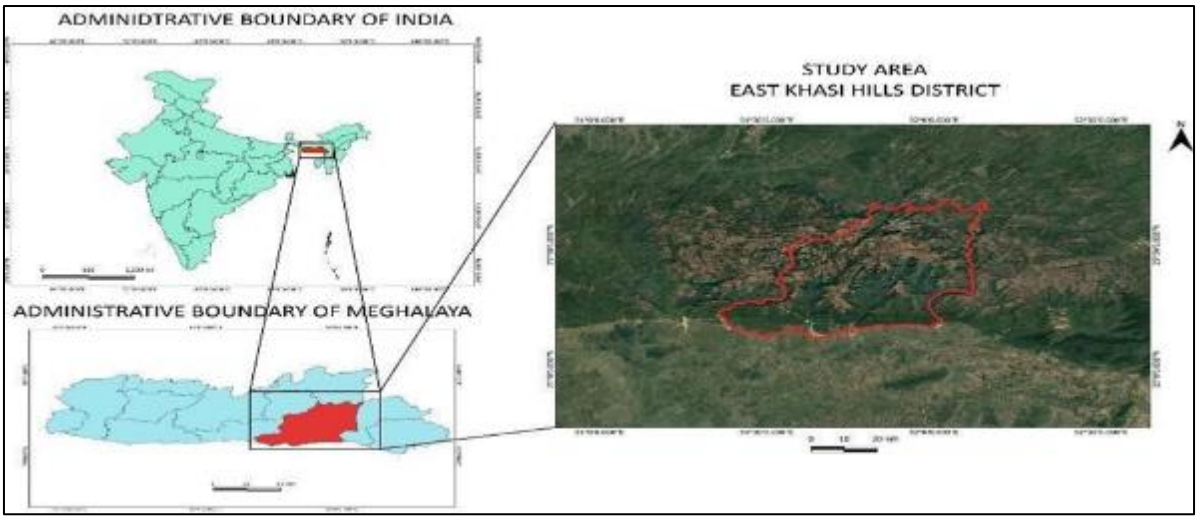

Figure 1: Location of Study area

(2011), the district had a population of 825,922, with 55.6% rural and 44.4% urban population, and a literacy rate of 84.15%. Agriculture, government services, tourism, trade, and other service activities are the major occupations. The challenging terrain, scattered settlements, and uneven transportation connectivity influence the accessibility and utilization of healthcare services, making the district suitable for analysing the spatial distribution and accessibility of Primary Health Centres (PHCs).

2 METHODOLOGY

2.1 Sources of Data

The present study is based on both primary and secondary sources of data.

2.1.1 Primary data

Were collected directly from the field through questionnaire surveys, personal interviews and field observations conducted in the selected Primary Health Centres (PHCs) and their surrounding villages. A total of 100 respondents were surveyed to obtain information regarding travel distance, travel time, mode of transportation, accessibility to PHCs, availability of nearby health facilities and socio-economic characteristics of the respondents.In addition, relevant information relating to healthcare infrastructure, manpower, service facilities and other PHC-related details was collected from the offices of the selected Primary Health Centres. Discussions with healthcare personnel and PHC officials also provided valuable information for the study.

2.1.2 Secondary data

Were collected from various published and unpublished sources, including Census of India publications, reports of the Directorate of Health Services, Government reports, books, journals, research articles, official websites and other relevant documents. Spatial data relating to administrative boundaries and PHC locations were used for map preparation and spatial analysis using GIS techniques.

3 SAMPLING TECHNIQUES AND SIZE

The present study employed Random sampling for the selection of Primary Health Centres (PHCs). Five PHCs, namely Smit PHC, Jongksha PHC, Pomlum PHC, Laitryngew PHC and Wahsherkhmut PHC, were randomly selected for detailed investigation in order to represent different geographical regions of East Khasi Hills District.A total of 100 respondents were selected from the service areas of the selected PHCs for the questionnaire survey. The respondents were selected through simple random sampling to obtain information regarding healthcare accessibility, travel distance,traveltime, mode of transportation and socio-economic characteristics. Thus, the study employed acombination of purposive sampling and simple random sampling to fulfil the objectives of the study.

3.1 Techniques Used

The study employed Geographic Information System (GIS), Nearest Neighbour Analysis (NNA), and Z-score analysis to assess the spatial distribution, accessibility, and adequacy of Primary Health Centres (PHCs) in East Khasi Hills District, Meghalaya.

3.2 Geographic Information System (GIS)

GIS was used to map the location of PHCs and analyse their spatial distribution within the study area. It helped in visualizing healthcare accessibility and identifying areas with limited healthcare coverage.

3.3 Nearest Neighbour Analysis (NNA)

Nearest Neighbour Analysis was used to determine the spatial distribution pattern of PHCs. The Nearest Neighbour Index (Rn) was calculated using the following formula:

- Rn = Do / De
- *Where: Rn = Nearest Neighbour Index,*
- *Do = Observed mean nearest neighbour distance,*
- *De = Expected mean nearest neighbour distance*
- *Rn < 1 = Clustered pattern, Rn = 1 = Random pattern, Rn > 1 = Dispersed pattern*

3.4 Z-Score Analysis

Z-score analysis was used to evaluate the adequacy and performance of selected PHCs based on healthcare indicators such as doctors, ANMs, staff nurses, supporting staff, laboratory technicians, inpatient services, outpatient services, population served, villages covered and bed availability. The Z-score was calculated using the following formula:

$$\mathbf{Z = (X - Mean) / Standard\ Deviation}$$

Where

- Z = Z-score value,
- X = Observed value,
- Mean = Average value of the indicator,
- Standard Deviation = Measure of variation from the mean.
- Positive Z-score values indicate above-average performance,
- whereas negative Z-score values indicate below-average performance compared with other selected PHCs.

4 RESULT

4.1 Spatial Distribution of Primary Health Centres

The spatial distribution of 22 Primary Health Centres (PHCs) in East Khasi Hills District reveals considerable variation in healthcare facility concentration and geographic coverage (Figure 2). The PHCs are distributed throughout the district; however, their spatial arrangement is not uniform. A relatively higher concentration of PHCs is observed in the central part of the district, where facilities such as Smit, Jongksha, Swer, Laitlyngkot, Laitryngew, and Khatarshnong are located in closer proximity to one another. These areas exhibit comparatively better healthcare coverage due to the shorter distances between neighbouring facilities. In contrast, the peripheral regions of the district display wider spacing between PHCs. Facilities such as Dangar, Lawbah, Diengpasoh, and Mawryngkneng are located in geographically dispersed areas characterized by rugged terrain and scattered settlements. The greater separation between facilities in these regions indicates relatively lower spatial accessibility to primary healthcare services. Overall, the distribution pattern suggests that although PHCs are present across the district, notable spatial disparities exist in terms of facility spacing and service accessibility. The observed pattern reflects the influence of terrain conditions, settlement distribution, and regional accessibility constraints on healthcare facility locations.

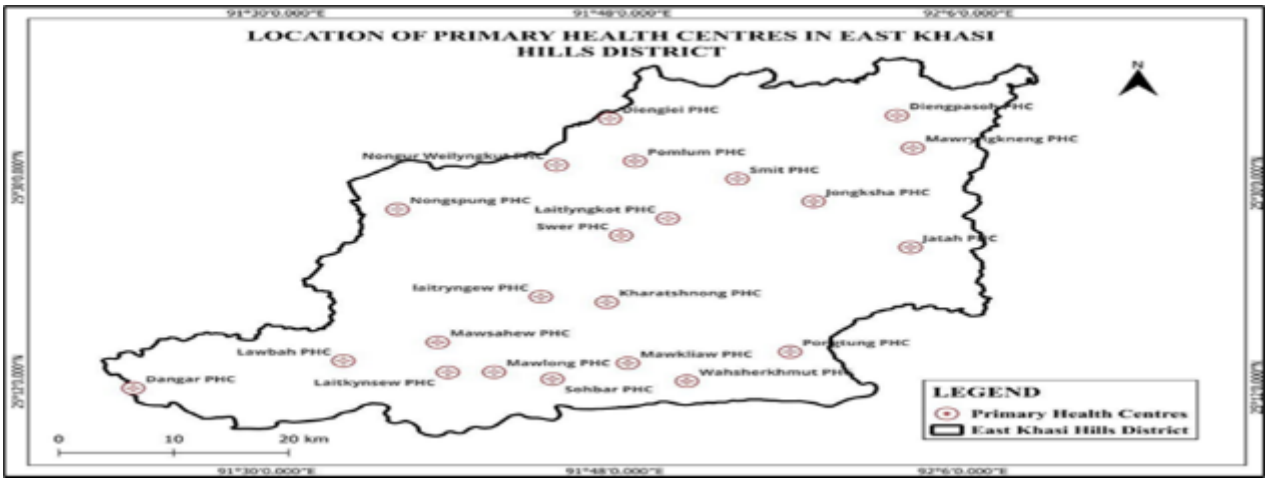

Figure 2: Location of Primary Health Centre's in East Khasi Hills District, Meghalaya

4.2 Nearest Neighbour Distance Analysis

The nearest neighbour distance analysis revealed substantial variation in the spacing of PHCs across East Khasi Hills District. The average nearest neighbour distance among the 22 PHCs was 6.9 km, indicating moderate separation between healthcare facilities (Figure 3).The shortest distance was recorded between Laitkynsew PHC and Mawlong PHC (4.02 km), followed by Swer PHC and Laitlyngkot PHC (4.93 km). These closely spaced facilities indicate areas with relatively higher healthcare service concentration. Conversely, the largest distance was observed between Dangar PHC and Lawbah PHC (18.80 km), (Table A) highlighting significant spatial gaps in healthcare coverage within certain parts of the district.

Table 1: Distance between Primary Health Centres (PHCs)

SL.NO	PHC NAME	NEAREST PHC	DISTANCE IN KM
1	Dangar PHC	Lawbah PHC	18.80
2	Lawbah PHC	Mawsahew PHC	8.75
3	Mawsahew PHC	Laitkynsew PHC	4.95
4	Laitkynsew PHC	Mawlong PHC	4.02
5	Mawlong PHC	Sohbar PHC	5.20
6	Sohbar PHC	Mawkliaw PHC	7.05
7	Mawkliaw PHC	Wahsherkhmut PHC	5.90
8	Wahsherkhmut PHC	Pongtung PHC	10.16
9	Khatarshnong PHC	Laitryngew PHC	5.79
10	Laitryngew PHC	Swer PHC	12.16
11	Swer PHC	Laitlyngkot PHC	4.93
12	Laitlyngkot PHC	Smit PHC	8.82
13	Smit PHC	Jongksha PHC	7.57
14	Jongksha PHC	Jatah PHC	11.27
15	Mawryngkneng PHC	Diengpasoh PHC	5.46
16	Pomlum PHC	Diengiei PHC	7.24
17	Diengiei PHC	NongtyngurWeilyngkut PHC	8.86
18	NongtyngurWeilyngkut PHC	Nongspung PHC	15.59
		AVG DISTANCE (D)	6.9

Figure 3: Nearest Neighbour Analysis

The variation in nearest neighbour distances demonstrates the uneven nature of healthcare accessibility. While some areas benefit from closely located healthcare facilities, others require residents to travel considerably longer distances to reach the nearest PHC.

4.3 Spatial Pattern of PHC Distribution

The calculated Nearest Neighbour Index (Rn) value of 1.2 indicates that the PHCs exhibit a random spatial distribution pattern. This finding suggests that healthcare facilities are neither strongly clustered nor uniformly dispersed across the district. Instead, their locations reflect a combination of geographical, demographic, and administrative factors.The random distribution pattern indicates that PHC placement has evolved according to local healthcare requirements and terrain conditions rather than following a systematic spatial arrangement. Although the overall distribution provides broad geographic coverage, significant differences in facility spacing remain evident between central and peripheral regions.

The spatial analysis identified important variations in healthcare accessibility across East Khasi Hills District. Central regions exhibitrelatively better healthcare coverage due to shorter inter-facility distances, whereas peripheral mountainous areas experience wider facility spacing and reduced accessibility. The maximum nearest neighbour distance of 18.80 km highlights the existence of underserved areas where residents may face greater travel burdens in accessing primary healthcare services.The results further indicate that terrain and settlement patterns play a crucial role in shaping the spatial organization of PHCs. Despite the district-wide presence of healthcare facilities, accessibility levels vary considerably across locations, emphasizing the need for targeted planning interventions in geographically remote regions. The calculated Nearest Neighbour Index (Rn) is 1.2.

4.4 Accessibility of Primary Health Centres

Healthcare accessibility is an important component in evaluating the effectiveness of healthcare service delivery. Accessibility is determined not only by the availability of healthcare facilities but also by factors such as travel time, distance, transportation facilities and the physical ability of people to reach healthcare institutions (Figure 4).In East Khasi Hills District, geographical conditions such as mountainous terrain, steep slopes, scattered settlements and variable road connectivity significantly influence healthcare accessibility. Therefore, the present study analysed accessibility conditions of the selected PHCs based on travel time, distance travelled, availability of transport facilities, nearby healthcare facilities and perception of PHC coverage among respondents.

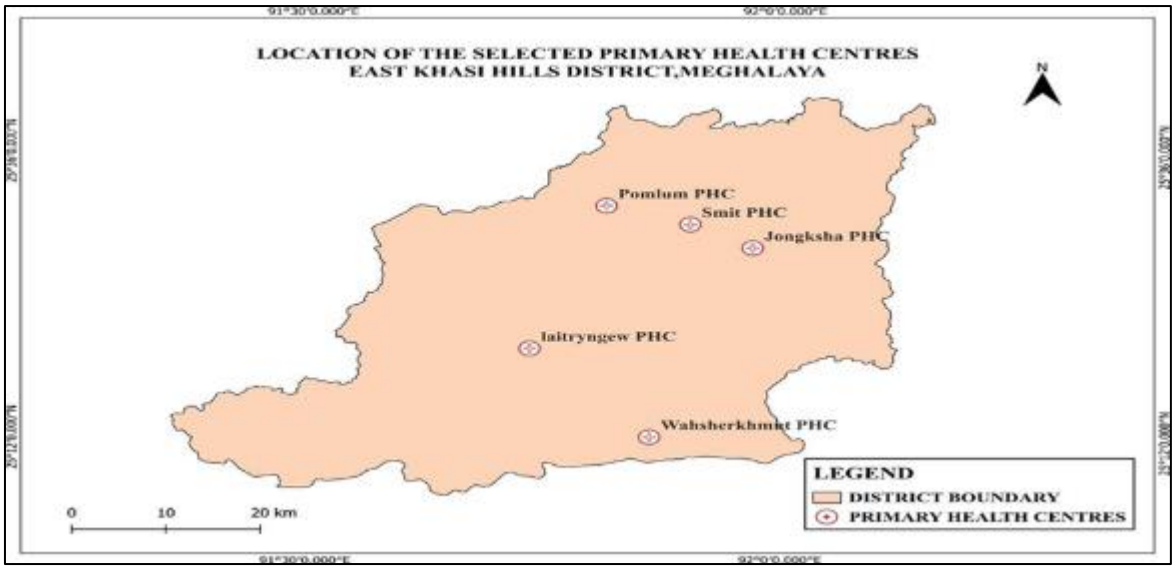

Figure 4: Location of Selected Primary Health Centres in East Khasi Hills District, Meghalaya

4.5 Z-SCORE ANALYSIS

Z-score analysis was employed to assess the adequacy of the selected Primary Health Centres (PHCs) in East Khasi Hills District. The analysis was carried out using various healthcare indicators, namely number of doctors, ANMs, staff nurses, supporting staff, laboratory technicians, in-patients, out-patients, population served, total villages served and number of beds. Positive Z-score values indicate above-average performance, whereas negative Z-score values indicate below-average performance in comparison with the other selected PHCs.

4.5.1 Smit PHC

The table 2 and Fig 5 present the healthcare indicators and Z-score values of Smit PHC.

Table 2: Indicators And Z-Score Values of Smit PHC

VARIABLES	Doctors	ANM	Staff Nurse	Staffs	Lab tech	IPD	OPD	Population Served	Villages covered	Beds
SMIT PHC	4	3	7	28	1	792	23361	35265	38	11
Z Score	0.73	-0.35	0.24	0.42	-0.7	1.74	0.96	0.13	-0.06	- 15

The table indicates that Smit PHC has 4 doctors, 3 ANMs, 7 staff nurses, 28 supporting staff, 1 laboratory technician, 792 In-Patients, 23361 Out-Patients and 11 beds. The PHC serves a population of 35,265 people distributed across 38 villages. In addition, Smit PHC recorded 792 in-patients and 23,361 out-patients during the reference period.

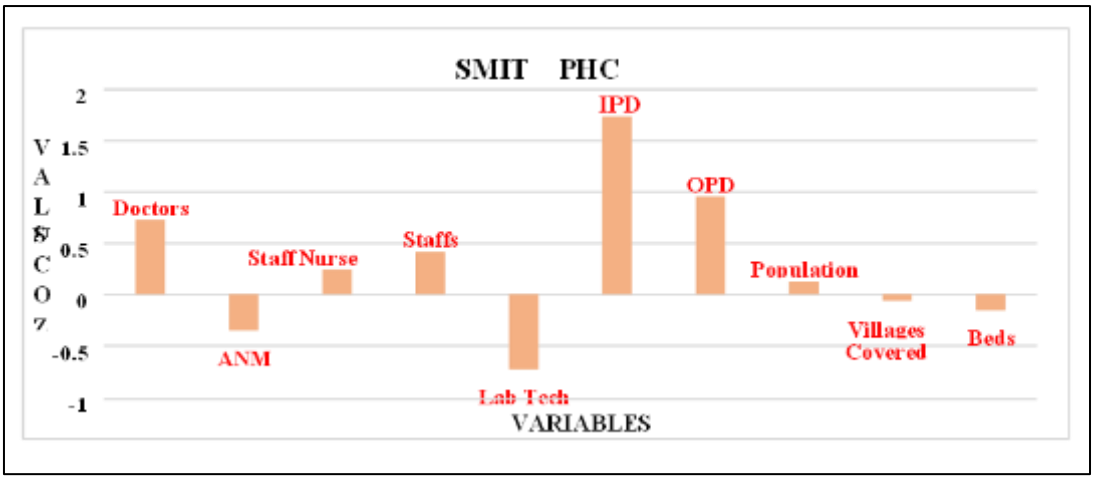

Figure 5: Smit PHC Z score graph

The Z-score graph shows that Smit PHC records positive values for doctors (0.73), staff nurses (0.24), supporting staff (0.42), in-patients (1.74), out-patients (0.96) and population served (0.13). The highest positive value is observed for in-patients, indicating that Smit PHC handles a comparatively larger number of admitted patients than most of the selected PHCs. Similarly, the positive value for out-patients indicates high utilization of healthcare services by the population. However, the PHC records negative values for ANMs (-0.35), laboratory technicians (-0.73), villages served (-0.06) and number of beds (-0.15). Although these values are slightly below the average, they do not indicate severe inadequacy (Fig 5).

Smit PHC demonstrates satisfactory performance in terms of healthcare service utilization and staffing. The high number of in-patients and out-patients suggests that the PHC adequately serves the surrounding population. Nevertheless, increasing the number of doctors, laboratory facilities and bed capacity would further improve service delivery.

4.5.2 Jongksha PHC

The table 3 shows that Jongksha PHC has 4 doctors, 3 ANMs, 8 staff nurses, 22 supporting staff, 2 laboratory technicians, 476 In-Patients, 7747 Out-Patients and 16 beds. The PHC serves 48,291 people distributed across 51 villages.

Table 3: Indicators And Z-Score Values of Jongksha PHC

VARIABLES	Doctors	ANM	Staff Nurse	Staffs	Lab-Tech	IPD	OPD	Population Served	Villages Covered	Beds
JONGKSHA PHC	4	3	8	22	2	476	7747	48291	51	16
Z Score Value	0.73	-0.35	0.84	-0.24	1.10	-0.27	-0.59	0.79	0.60	1.76

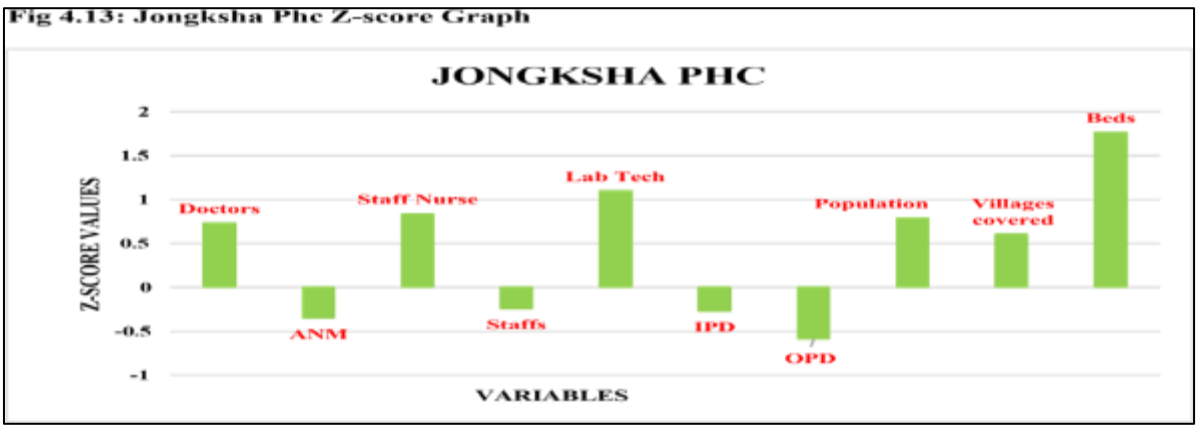

Figure 6: Jongksha PHC Z score Graph

The Z-score values and graph reveal positive performance for Doctors (0.73), staff nurses (0.84), laboratory technicians (1.10), population served (0.79), villages served (0.60) and number of beds (1.76). The highest positive value is recorded for bed availability, indicating that Jongksha PHC possesses comparatively better bed capacity than the other selected PHCs. However, the PHC records negative values for ANMs (-0.35), supporting staff (-0.24), inpatients (-0.27) and out-patients (-0.59)(Fig 6).These negative values suggest that the utilization of healthcare services and some categories of manpower are comparatively lower than the average. Despite these limitations, the presence of adequate staff nurses, laboratory technicians and bed facilities indicates that Jongksha PHC possesses relatively good healthcare infrastructure. Therefore, Jongksha PHC can be considered capable of adequately serving the population within its service area.

4.5.3 Wahsherkhmut PHC

The Table 4 shows the Wahsherkhmut PHC has 2 doctors, 5 ANMs, 4 staff nurses, 16 supporting staff, 1 laboratory technician, 480 In-Patients, 487 Out-Patients and 10 beds. The PHC serves a comparatively smaller population of 11,759 people across 11 villages.

Table 4: Indicators And Z-Score Values of Wahsherkhmut PHC

VARIABLES	Doctors	ANM	Staff Nurse	Staffs	Lab-Tech	IPD	OPD	Population Served	Villages Covered	Beds
WAHSH ER-KHMU T PHC	2	5	4	16	1	480	487	11759	11	10
Z Score Value	-1.10	1.40	-1.55	-0.90	-0.73	-0.25	-1.31	-1.07	-1.44	-0.54

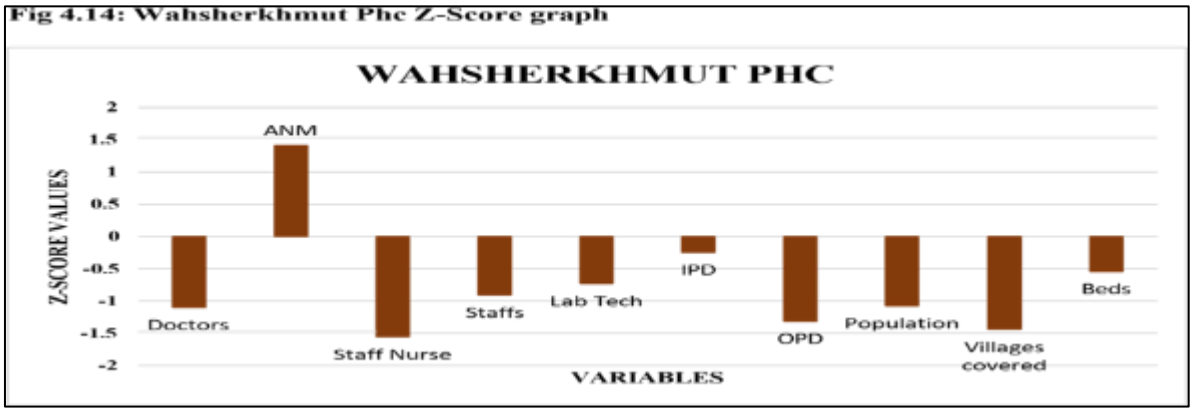

Figure 7: Wahsherkhmust PHC Score Graph

The Z-score graph shows positive values for ANMs (1.40), indicating that Wahsherkhmut PHC possesses a comparatively higher number of ANMs than the average. Adequate ANM availability is beneficial for maternal and child healthcare services. However, the PHC records negative values for doctors (-1.10), staff nurses (-1.55), supporting staff (-0.90), laboratory technicians (-0.73), in-patients (-0.25), out-patients (-1.31), population served (-1.07), villages served (-1.44) and bed facilities (-0.54) (Fig7). The strongly negative values for staff nurses, population served and villages covered indicate that the PHC performs below the average in several indicators. The low number of out-patients also suggests comparatively lower healthcare utilization. Although Wahsherkhmut PHC serves a smaller population, improvements in staffing levels and infrastructure would strengthen healthcare service delivery. Overall, Wahsherkhmut PHC adequately serves its existing population, but additional healthcare manpower and infrastructural support are required to enhance the quality of healthcare services.

4.5.4 Laitryngew PHC

Laitryngew PHC has 2 doctors, 2 ANMs, 6 staff nurses, 17 supporting staff, 1 laboratory technician, 386 In-Patients, 12997 Out-Patients and 10 beds. The PHC serves a population of 13,748 people distributed across 33 villages(Table 5).

Table 5: Indicators and Z-Score Values of Laitryngew PHC

VARIABLES	Doctors	ANM	Staff Nurse	Staffs	Lab-Tech	IPD	OPD	Population Served	Villages Covered	Beds
LAITRYNGEW PHC	2	2	6	17	1	386	12997	13748	33	10
Z Score Value	-1.10	-1.23	-0.36	-0.79	-0.73	-0.84	-0.07	-0.98	-0.32	-0.54

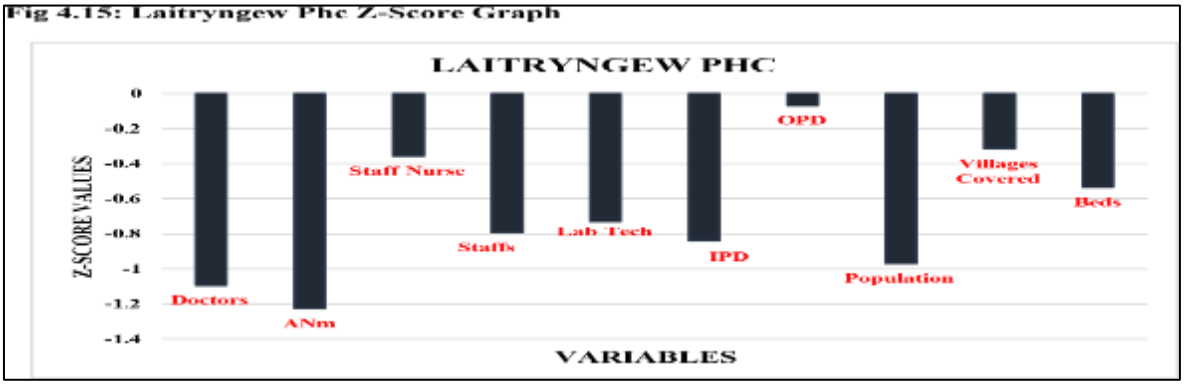

Figure 8: Laitryngew PHC Z score Graph

The Z-score values indicate positive performance only for staff nurses (-0.36 is close to average), supporting staff (-0.79), out-patients (-0.07) and villages served (-0.32). Most of these values remain close to the average. The PHC records negative values for doctors (-1.10), ANMs (-1.23), supporting staff (-0.79), laboratory technicians (-0.73), in-patients (-0.84), population served (-0.97) and bed availability (-0.54). The negative value for ANMs suggests inadequate availability of maternal and child healthcare personnel(Fig 8). The relatively low number of in-patients indicates limited utilization of inpatient services. Similarly, the lower population served reflects a comparatively smaller service area. Laitryngew PHC performs moderately but remains below average for several indicators. Strengthening manpower, especially doctors and ANMs, together with improved infrastructure, would increase the adequacy of healthcare services.

4.5.5 Pomlum PHC

Pomlum PHC has 4 doctors, 4 ANMs, 8 staff nurses, 38 supporting staff, 2 laboratory technicians and 10 beds. The PHC serves the largest population among the selected PHCs, with 54,886 people distributed across 63 villages (Table 6).

Table 6: Indicators and Z-Score values of Pomlum PHC

VARIABLES	Doctors	ANM	Staff Nurse	Staffs	Lab-Tech	IPD	OPD	Population served	Villages Covered	Beds
POMLUM PHC	4	4	8	38	2	459	23937	54886	63	10
Z-Score Values	0.73	0.53	0.84	1.52	1.10	-0.38	1.01	1.13	1.21	-0.54

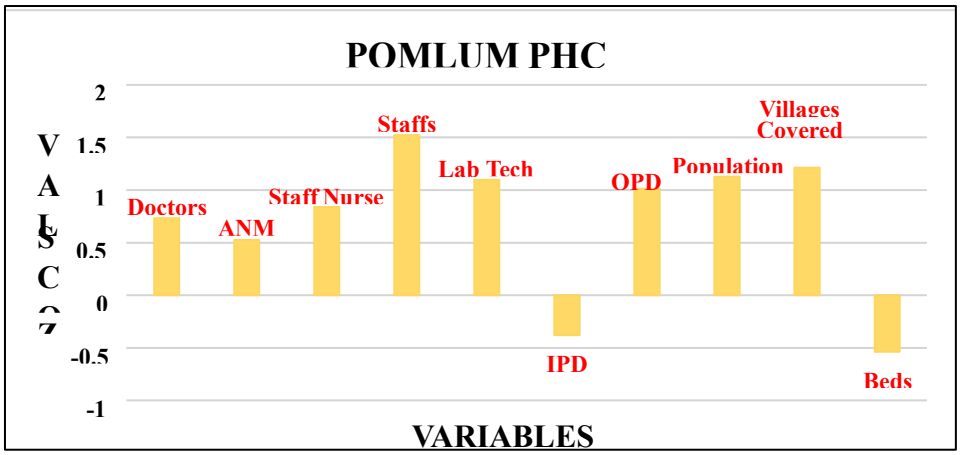

Figure 9: Pomlum PHC Z Score Graph

The Z-score graph reveals positive values for doctors (0.73), ANMs (0.53), staff nurses (0.84), supporting staff (1.52), laboratory technicians (1.10), out-patients (1.01), population served (1.13) and villages served (1.21) (Fig 9).The highest positive value is observed for supporting staff, indicating comparatively stronger manpower support. The PHC records only a few negative values for in-patients (-0.38) and bed facilities (-0.54). Despite serving the largest population and covering the highest number of villages, the PHC possesses only 10 beds, which may place additional pressure on healthcare resources. Nevertheless, the overall positive Z-score pattern indicates that Pomlum PHC performs better than the majority of the selected PHCs. The availability of adequate manpower and high service utilization demonstrate that the PHC effectively serves a large population.

4.6 Comparative Performance of Selected PHCs

The comparative Z-score analysis reveals considerable disparities among the selected Primary Health Centres (PHCs) in East Khasi Hills District. Pomlum PHC emerged as the best-performing facility, recording positive Z-scores for most healthcare indicators and serving the largest population across the highest number of villages.

Table 7: Comparative Performance of Selected PHCs

PHC	Major Strengths (Positive Z-Scores)	Major Weaknesses (Negative Z-Scores)
Smit PHC	High IPD (1.74), OPD (0.96), Doctors (0.73), Staff Nurses (0.24)	Lab Technicians (-0.73), ANMs (-0.35), Beds (-0.15)
Jongksha PHC	Beds (1.76), Lab Technicians (1.10), Staff Nurses (0.84), Population Served (0.79)	OPD (-0.59), IPD (-0.27), Supporting Staff (-0.24)
Wahsherkhmut PHC	ANMs (1.40)	Staff Nurses (-1.55), Villages Covered (-1.44), OPD (-1.31), Doctors (-1.10)
Laitryngew PHC	Near-average OPD (-0.07), Villages Covered (-0.32)	ANMs (-1.23), Doctors (-1.10), IPD (-0.84), Beds (-0.54)
Pomlum PHC	Supporting Staff (1.52), Villages Covered (1.21), Population Served (1.13), OPD (1.01), Lab Technicians (1.10)	Beds (-0.54), IPD (-0.38)

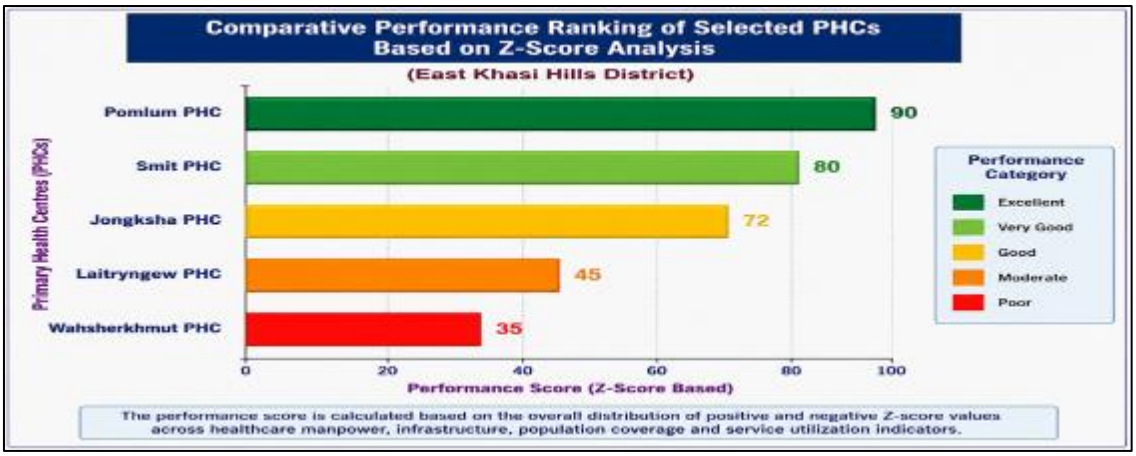

Figure 10: Comparative Performance of Selected PHCs

Smit PHC also demonstrated strong performance, particularly in healthcare utilization, with the highest in-patient and high out-patient attendance. Jongksha PHC showed relatively strong infrastructure, especially in terms of bed availability and laboratory services (Table 7 and Figure 10). In contrast, Wahsherkhmut PHC and Laitryngew PHC exhibited several negative Z-scores, indicating deficiencies in healthcare manpower, infrastructure, and service utilization. Overall, the findings suggest that Pomlum, Smit, and Jongksha PHCs provide comparatively better healthcare services, whereas Wahsherkhmut and Laitryngew PHCs require additional resources and infrastructural improvements to enhance healthcare delivery.

5 DISCUSSION

The present study examined the spatial distribution, accessibility, and adequacy of Primary Health Centres (PHCs) in East Khasi Hills District, Meghalaya, using Geographic Information System (GIS), Nearest Neighbour Analysis (NNA), field survey data, and Z-score analysis. The findings reveal important spatial and functional variations in healthcare service provision across the district.The spatial distribution analysis demonstrated that PHCs are geographically dispersed throughout East Khasi Hills District, ensuring broad healthcare coverage. However, the distribution is not uniform across the district. PHCs are more closely spaced in the central region, where population concentration and transportation facilities are relatively better, whereas peripheral and mountainous areas exhibit greater distances between healthcare facilities. The Nearest Neighbour Index (Rn = 1.2) indicates a random spatial distribution pattern. This suggests that the location of PHCs has been influenced by a combination of geographical conditions, settlement patterns, population distribution, and administrative healthcare planning rather than by a systematic spatial arrangement.The accessibility assessment indicates that the majority of respondents perceive PHCs as reasonably accessible. Most respondents require less than 30 minutes to reach healthcare facilities, and more than ninety percent reported that PHCs are accessible. These findings indicate that the existing PHC network plays a significant role in delivering primary healthcare services to rural populations. Nevertheless, accessibility challenges remain in remote areas where rugged terrain, steep slopes, inadequate transportation facilities, and poor road connectivity increase travel time and distance. The fact that 42 percent of respondents travel more than 5 kilometres to reach a PHC highlights the continuing influence of geographical barriers on healthcare utilization.Transportation plays a crucial role in healthcare accessibility within the district. Public transport represents the most common mode of travel to healthcare facilities, followed by walking. The dependence on public transport indicates the importance of transportation infrastructure in ensuring access to healthcare services. Any disruption in transport services may therefore significantly affect healthcare utilization, particularly among vulnerable populations such as elderly individuals, pregnant women, and children.

The findings further demonstrate that healthcare accessibility is strengthened by the presence of supporting healthcare facilities such as Sub-Centres and Community Health Centres (CHCs). More than sixty percent of respondents reported the availability of nearby Sub-Centres, which serve as important first-contact healthcare facilities and reduce the burden on PHCs. This hierarchical healthcare structure contributes to improved healthcare delivery and accessibility throughout the district.The Z-score analysis revealed substantial differences among the selected PHCs regarding healthcare manpower, infrastructure, service utilization, and population coverage. Pomlum PHC emerged as the strongest-performing healthcare facility among the selected centres. The PHC recorded positive Z-score values for most healthcare indicators, including doctors, ANMs, staff nurses, supporting staff, laboratory technicians, population served, and villages covered. Despite serving the largest population and the highest number of villages, Pomlum PHC continues to function effectively due to its relatively strong manpower base and healthcare infrastructure.Smit PHC also demonstrated satisfactory performance, particularly in terms of inpatient and outpatient attendance. The high

utilization of healthcare services indicates strong public confidence in the facility and highlights its importance within the district healthcare system. However, improvements in laboratory services and bed capacity would further strengthen service delivery.

Jongksha PHC exhibited comparatively better infrastructure, particularly regarding bed availability and laboratory facilities. The facility serves a large population distributed across numerous villages, indicating its importance as a healthcare provider within the district. Although patient attendance is relatively lower compared with some other PHCs, the availability of healthcare resources suggests adequate service capacity.In contrast, Wahsherkhmut PHC and Laitryngew PHC displayed relatively weaker performance across several indicators. Both PHCs recorded negative Z-score values for important healthcare variables, including doctors, staff nurses, laboratory technicians, and bed facilities. Although these PHCs adequately serve their existing populations, deficiencies in healthcare manpower and infrastructure may limit their capacity to meet future healthcare demands. The findings suggest the need for targeted investments in healthcare personnel, equipment, and infrastructure to improve service quality and healthcare accessibility in these areas.

The results highlight the importance of integrating spatial analysis with healthcare planning. GIS-based techniques provide valuable insights into healthcare accessibility patterns and help identify underserved areas requiring additional healthcare investments. In geographically complex regions such as East Khasi Hills District, spatial planning becomes particularly important because terrain characteristics significantly influence healthcare accessibility.The findings of this study are consistent with previous healthcare accessibility research conducted in mountainous and rural regions, which has shown that geographical barriers, transportation infrastructure, and healthcare facility distribution significantly influence healthcare utilization patterns. The study confirms that physical accessibility remains a critical determinant of healthcare access even when healthcare facilities are geographically distributed throughout a region.Overall, the study demonstrates that while the existing PHC network provides substantial healthcare coverage across East Khasi Hills District, disparities remain in terms of accessibility, infrastructure, and service capacity. Addressing these disparities through improved healthcare planning, infrastructure development, and strategic resource allocation would contribute significantly towards achieving equitable healthcare access throughout the district.

6 CONCLUSION

The study provides valuable insights into the current status of primary healthcare accessibility and service provision within the district. The spatial analysis revealed that PHCs are distributed throughout the district and provide broad geographical coverage. The accessibility assessment indicates that the majority of respondents can access PHCs within reasonable travel times and distances. Most respondents perceive the selected PHCs as accessible, and the availability of supporting healthcare facilities such as Sub-Centres and CHCs further strengthens healthcare delivery. Nevertheless, geographical barriers continue to affect healthcare accessibility in remote and mountainous areas where long travel distances, poor road conditions, and limited transportation facilities create challenges for healthcare utilization. In conclusion, although the existing PHC network adequately serves a large proportion of the population, achieving equitable healthcare access requires continuous improvement in healthcare infrastructure, service capacity, and spatial planning. Strengthening these aspects will contribute towards improving public health outcomes and ensuring sustainable healthcare development in East Khasi Hills District, Meghalaya.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare no conflict of interest.

Statement of ethical approval

The study was conducted following institutional ethical guidelines.

Statement of informed consent

Informed consent was obtained from all participants prior to data collection.

REFERENCES

[1] Saravanabavan, V., & Vinothini, C. (2026). Assessment Of Healthcare Performance: Knowledge, Attitude, Behavioral Characteristics of Patients and Spatial Distribution of PHC's In Sepahijala District, Tripura, India. *IRE Journals*, *9*(11), 97-108.DOI: https://doi.org/10.64388/IREV9I11-1717261

[2] Saravanabavan, V., Vinothini, C., Vadivel, S., Sanjeevi Prasad, S., Katturajan, K., & Balaji, D. (2025). Assessing the performance of primary health centres in Meghalaya: An automatic linear modelling. *International Journal of Science and Research Archive*, *16*(01), 454-465.https://doi.org/10.30574/ijsra.2025.16.1.2010

[3] Vinothini, C., Suja Rose, R.S & Saravanabavan, V. (2025) Patients' Perception and Health care Accessibilityof Primary Health care centre in Madurai District-A Geo-Medical Study. December 2025.Annals of the National Association Of Geographers India 45(2):233-249 DOI:10.32381/ATNAGI.2025.45.02.8

[4] Vinothini, C., Suja Rose, R S., Saravanabavan, V., & Vadivel, S. (2025). Factors influencing healthcare accessibility in Madurai District: A spatial and factor analytical approach. *International Journal of Engineering Development and Research*, *13*(3), 20-30.www.ijedr.org

[5] Saravanabavan, V., Nongspung, C., Vinothini, C., & Vadivel, S. (2025). Healthcare Accessibility in East Khasi Hills, Meghalaya, India: Age, Gender, and Socioeconomic Barriers to Primary Health Centre Access. *Asian Journal of Geographical Research*, *8*(3), 488-505. https://doi.org/10.9734/ajgr/2025/v8i3313

[6] Vinothini, C., Suja Rose, R. S., Saravanabavan, V. (2026). Assessing Primary Healthcare Performance and Patient Perception Using Kernel Density Estimation in Madurai District. Journal of Advance and Future Research, Volume 4, Issue 4 April 2026,537-548. https://rjwave.org/jaafr/viewpaperforall.php?paper=JAAFR2604192

[7] Saravanabavan, V., Cajee, L., Sangma, M. C., & Vinothini, C. (2025). Spatial Distribution and Service Coverage Analysis of Primary Health Centres in South West Garo Hills District, Meghalaya, India. *Asian Journal of Geographical Research*, *8*(4), 389-400.https://doi.org/10.9734/ajgr/2025/v8i4344

[8] Sengnang S Mark, V.Saravanabavan, C.Vinothini (2026) Perception of Health Tourism in enhancing the quality of life of the Garo community: A case study of Daribokgre village, East Garo Hills, Meghalaya.International Journal of Research Publication and Reviews 7 (3), 3469-3477.https://doi.org/10.55248/gengpi.07.0326.20635

[9] Reshma CU, SK Sheheersha, V Saravanabavan (2014)Enhancing The Quality And Accessibility Of Geographic Learning Through Modern Instructional Strategies In The School: Its Implications And Opportunities.IOSR Journal of Research & Method in Education (IOSR-JRME) Volume 4, Issue 3 Ver. II (May-Jun. 2014), PP 25-30

[10] Engjaipi, L., Saravanabavan, V., & Vinothini, C. (2025). Gender-wise travel pattern and utilization of primary health centers of Karbi Anglong district, Assam. *International Journal of Science and Research Archive*, *14*(03), 1320-1330.Article https://doi.org/10.30574/ijsra.2025.14.3.0779

[11] Radhakrishnan, R., & Vaithialingam, S. (2023). Exploring the suitability of groundwater for domestic water quality and irrigation purpose in Dindigul district, Tamil Nadu. In *Surface and groundwater resources development and management in semi-arid region: strategies and solutions for sustainable water management* (pp. 253-277). Cham: Springer International Publishing.https://doi.org/10.1007/978-3-031-29394-8_14

[12] Vinothini, C., Suja Rose, R. S., & Saravanabavan, V. (2024). Geospatial analysis of communicable diseases in Madurai district. *International Journal of Humanities Social Science, and Management*, *4*(3), 1145-1153.

[13] Vinothini, C., Saravanabavan, V., & Suja Rose, R. S. (2025). Travel behaviour of child patients and health care accessibility of PHC in Madurai District, Tamilnadu. *International Research Journal of Education and Technology*, *7*(02)., 283-295

[14] Saravanabavan, V., Reejo, R. J., Neethidevi, A., & Jayashree, R. (2006). Travel and health care utilization pattern of patients in Vadippati panchayat union: A micro level study using GIS. *Journal of Deccan Geographer*, *44*(2), 97-108.

[15] Saravanabavan,V., R Sudharsan, D Balaji, R Rahamath Nisha.(2014)Patient's perception and epidemiological characteristics of dengue in Madurai city-using factor analysis,International Journal of Mosquito Research 1 (2), 19-26

[16] Delamater, P. L., Messina, J. P., Shortridge, A. M., & Grady, S. C. (2019). Measuring geographic access to health care: Raster and network-based methods. *International Journal of Health Geographics, 18*(1), 15. https://doi.org/10.1186/s12942-019-0186-3

[17] Wong, S., & Regan, S. (2009). Patient perspectives on primary health care in rural communities: effects of geography on access, continuity and efficiency. *Rural and remote health*, *9*(1), 1-12.

[18] Eswari, S., V Saravanabavan., D. Balaji . (2021). Structural equation modelling approach to determine the mother and child health care in Madurai district, Tamil Nadu. *International Journal of Scientific Research in Science and Technology*,volume 8, Issue 2, pp 335-344. https://doi.org/10.32628/IJSRST218256

[19] Saravanabavan, V. (2011, April). GIS analysis of pedestrian problem and spatial risk areas for each buffer zone in uraban cities a case study of Madurai city in Tamlnadu, India. In *1st International symposium held on* (pp. 19-21).

[20] Vinothini C, Suja Rose R.S, Saravanabavan V (2026)Geo- Spatial Distribution and Determinants of Nutritional Disorders among Primary Health Care Patients in Madurai .District International Journal Advanced Research Publications 2 (05), 01-21DOI: https://doi-doi.org/101555/ijrpa.5168

[21] Eswari, S., Saravanabavan, V., Vinothini, C., & Balaji, D. (2025). Mother and Child Health Care In Madurai District: A Structural Equation Modelling Approach. The Indian Geographical Journal, *100*(1), 39-54.

[22] Saravanabavan, V., &Shanmuganandan, S. (1994). Geo-Medical analysis of Leprosy patients in Tamilnadu. *The Indian Geographical Journal*, *69*(2), 135-139.

[23] Saravanabavan, V., Thabah, M., & Vinothini, C. (2026). Age-wise travel patterns and utilization of primary health Centres in Eastern West Khasi Hills District, Meghalaya: A GIS-Based Analysis.International Journal of Science and Research Archive 20 (02), 192–205.https://doi.org/10.30574/ijsra.2026.20.2.1600

[24] Vinothini, C., Saravanabavan, V., & Rose, R. S. (2024). Travel patterns of adult patients to primary health centers in Madurai district: A public health perspective. *International Journal of Science and Research Archive*, *13*(1), 141-149.https://doi.org/10.30574/ijsra.2024.13.1.1605

[25] Vinothini, C., Saravanabavan, V., & Emayavaramban, V. (2022). Location Accessibility of PHC and Health care travel performance in Madurai District. *International Journal of Innovative Science and Research Technology*, *7*(12), 2456-2165.

[26] Saravanabavan, V., Vinothini, C., Suja Rose, R. S., & Balaji, D. (2025). A Geo-Chemical Study of Water Pollution Due to the Tanning Industry: A Case Study of Dindigul District, Tamilnadu, India. In *Groundwater Resource Management Planning Strategies: A Geospatial Approach: Volume 1* (pp. 651-683). Cham: Springer Nature Switzerland.https://doi.org/10.1007/978-3-031-88870-0_25

[27] Saravanabavan, V., Sangma, N. N., & Vinothini, C. (2024). Spatial distribution and pattern of location in primary health centers in West Garo Hills District, Meghalaya. *International Journal of Research Publication and Reviews*, *5*(11), 694-701.DOI : https://doi.org/10.55248/gengpi.5.1124.3126

[28] Vinothini, C., Neethidevi, A., & Saravanabavan, V. (2019). Health impact and nine fold classification of land use change in Nilakottai Taluk, Dindigul District, Tamil Nadu. *International Journal of Geography, Geology and Environment*, *1*(1), 80-86.

[29] Sudharsan, R., & Saravanabavan, V. (2019). Availability and Utilization of Primary Healthcare Centre in Thanjavur District, Tamilnadu. *International Journal of Scientific Research in Science and Technology*, *6*(4), 288-297.https://doi.org/10.32628/IJSRST196451

[30] Umasankar, R. V., & Saravanabavan, V. (2024). Geospatial analysis of health care resource allocation in Karur District: Insights from GIS. *Shodhkosh: Journal of Visual and Performing Arts*, *5*(1), 646-655. DOI10.29121/shodhkosh.v5.i1.2024.2040

[31] RahamathNisha,R., V.Saravanbavan, R.SureskumarEffects of Population Density and Air Pollution on Covid -19 Morbidity and Mortality in India Using GIS. International Journal of Contemporary Medical Research 8 (8), H1-H11.DOI: http://dx.doi.org/10.21276/ijcmr.2021.8.8.8

[32] Vinothini, C., & Saravanabavan, V. (2022). Spatial Distribution of Emerging Diseases in Madurai District: A Geo Medical Study. *International Journal of Innovative Science and Research Technology*, *7*(6), 2456-2165.

[33] Vinothini, C., Suja Rose, R. S., & Saravanabavan, V. (2024). Assessment of primary health care accessibility and patients' perception in Madurai district: a geo-medical study. *GeoJournal*, *89*(5), 211. https://doi.org/10.1007/s10708-024-11208-1

[34] Saravanabavan, V. (2013). Patients perception and travel behavior pattern in primary health care center in Haripad block-A micro Geo-medical study. *Journal of Language in India*, *13*(4), 194-207.www.languageinindia.com

[35] Saravanabavan, V., Lekha, C. A., Aparna, T., Nisha, R. R., Balaji, K. K., & Kanna, S. V. (2021). Spatio-temporal variation of dengue in Kozhikode District, Kerala: A medico geographical study. *International Journal of Mosquito Research*, *8*(1 Part B), 130-140.

[36] Danyon DameshwaJyrwa ,V Saravanabavan, Laitpharlang Cajee ,C Vinothini (2025) Spatial analysis and efficiency of healthcare delivery system in Meghalaya State, India: A 'Z' Score Approach. International Journal of Science and Research Archive ,15 (01), 1312-1324.https://doi.org/10.30574/ijsra.2025.15.1.1148

[37] Nemcha Mate, T. , Saravanabavan, V., & Vinothini, C. (2025). Consumption of Areca Nut and its Socioeconomic and Health Impacts in Shillong, Meghalaya-A Geographical Analysis. *International Journal of Research Publication and Reviews*, *6*(11), 899-909.https://doi.org/10.55248/gengpi.06.1125.3842

[38] Vinothini, C; SujaRose,R S; Saravanabavan and Vadivel,S (2026). Determinants of Healthcare Access and Patient Satisfaction in Rural and Semi- Urban Madurai District, India: A Geo- Medical Analysis Using Structural Equation Modeling. Annals of Nursing-A Semi-Annual International Journal,4(1):17-33. Doi:10.5937/annnur4-66903.

[39] Ramphila A Shatsang., Saravanabavan, V., & Vinothini, C. (2025). Health and Socio-Economic Analysis of Adolescent Drug Abuse in Ukhrul District, Manipur. *International Journal of Research Publication and Reviews*, *6*(10), 2479-2488.DOI: https://doi.org/10.55248/gengpi.6.1025.3641

[40] Eswari, S., Saravanabavan, V., & Balaji, D. (2020). Infant neonatal and post neonatal mortality in Madurai district, Tamil Nadu, India: A Geomedical Study. *International Journal of Geography, Geology and Environment*, *2*(2), 102-112.

[41] Rahamath Nisha, R., Saravanabavan, V., & Sureshkumar, R. (2020). Emerging COVID-19 epidemiology in Tamil Nadu India using GIS. *International Journal of Contemporary Medical Research*, *7*(8), H10-H17.http://dx.doi.org/10.21276/ijcmr.2020.7.8.15

[42] Vinothini, C., & Saravanabavan, V. (2023). Determinants of health care facilities and patients 'accessibility to PHC in Madurai district. *International Journal of Geography, Geology, and Environment*, *5*(2), 17-22.

[43] Saravanabavan, V., Debbarma, K., & Vinothini, C. (2025). Primary health care access and socio-economic conditions of the patients in Sepahijala District, Tripura. *International Journal of Science and Research Archive*, *6*(1), 295-305. Doi : 10.55248/gengpi.6.0125.0207

[44] Vinothini C., Suja Rose R. S., Saravanabavan V.(2026)Network Analysis of Road Accessibility in Madurai District, Tamilnadu.International Journal Advanced Research Publications 2 (08), 01-20.https://doi-doi.org/101555/ijarp.1216

[45] Vinothini C, R.S. Suja Rose, V. Saravanabavan (2024) Demographic and Socio-economic Conditons of hte Patients of the Primary Health Care Centers in Madurai District, Tamilnadu, Indian Journal of Spatial Science 15 (4), 50-55. https://doi.org/10.5281/zenodo.14551205

[46] Saravanabavan, V. (1996). Bicycles and health-a geo medical study of Madurai city. In *Velo Australis and Velo-City'96, International Bicycle Conference, 1996, Fremantle, Western Australia*.

[47] Saravanabavan V , MekyrshanborThabah , C. Vinothini(2026) Assessment of Patient Satisfaction with Primary Health Centre Services in Eastern West Khasi Hils Distict , Meghalaya: A Z - Score Analysis.International Journal of Research Publication and Reviews 7 (7), 3478-3488

[48] Rahamath Nisha R, V.Saravanabavan, C.Vinothini(2026) Rural-Urban Variation in Dengue Vector Breedings Dynamics in Madurai District, Ta.ilNadu,India: A Geo-Medical Study,Asian Journal of Geographical Research 9 (3), 345-367 .https://doi.org/10.9734/ajgr/2026/v9i3433

[49] Vinothini, C., Rose, R. S., Vadivel, S., & Saravanabavan, V. (2025). Determinants of primary healthcare centresutilisation: A geo-statistical study of healthcare access in Madurai district, Tamil Nadu. *International Journal of Science and Research Archive*, *15*(02), 1557-1567.https://doi.org/10.30574/ijsra.2025.15.2.1544

[50] Saravanabavan, V., Emayavaramban, V., Thangamani, V., Manonmani, I. K., Rose, R. S., Balaji, D., ... & Vinothini, C. (2023). Spatial variation of covid-19 morbidity status and identification of risk zone in Tamil Nadu (India) during first wave. *GeoJournal*, *88*(2), 1341-1354. https://doi.org/10.1007/s10708-022-10680-x

[51] Saravanabavan, V., Vinothini, C., Balaji, D., Alok, M., Arya, M.,& Athira, R. (2022). A Geo-spatial approach on COVID-19 mortality in Tamil Nadu. *International Journal of Geography, Geology and Environment*, *4*(1), 123-131.

[52] Vinothini, C., Rose, R. S., & Saravanabavan, V. (2024). Spatial distribution and female travel behavior: Enhancing primary health care services in Madurai District. *International Journal of Engineering applied Sciences and Technology*, *9*(05), 2455-2143.

[53] Sheheersha, S. K., & Saravanabavan, V. (2021). Geo-Medical Analysis of Telemedicine Based Mobile Tele-Ophthalmology Screening For Cataract Cases in Thiruvananthapuram District, Kerala, India. *IOSR Journal Of Humanities And Social Science*, *26*(10), 1-7.http:// DOI: 10.9790/0837-2610070107

[54] Guagliardo, M. F. (2004). Spatial accessibility of primary care: Concepts, methods and challenges. *International Journal of Health Geographics, 3*(1), 3. https://doi.org/10.1186/1476-072X-3-3

[55] Penchansky, R., & Thomas, J. W. (1981). The concept of access: Definition and relationship to consumer satisfaction. *Medical Care, 19*(2), 127–140.

[56] Saravnabavan, V., Ganesan, J., Vinothini, C., & Balaji, D. (2026). The Impact of BMI on the Health Status of Tea Plantation Workers in the Nilgiris, Tamil Nadu, India. Journal of Complementary and Alternative Medical Research, 27(2), 59-74. DOI: https://doi.org/10.9734/jocamr/2026/v27i2741

[57] Saravanabavan, V., &Shanmuganandan, S. (1996). Pattern of leprosy treatment and health care situation in Tamil Nadu. *Annals of the National Association of Geographers, India*, *16*(2), 25-35.

[58] Khakchang Debarma, V.Saravanabavan, C. Vinothini (2026) Patients Perception, Attitude and Behavvioural Characteristic of PHC in Sepahijala District , Tripura, India . International Journal of advanced Research Publications, Volume 02 , Issue 05,pp 01-19.DOI: https://doi-doi.org/101555/ijarp.4952

[59] McLafferty, S. L. (2003). GIS and health care. *Annual Review of Public Health, 24*, 25–42. https://doi.org/10.1146/annurev.publhealth.24.100901.140843

[60] Wang, F. (2012). Measurement, optimization, and impact of health care accessibility: A methodological review. *Annals of the Association of American Geographers, 102*(5), 1104–1112. https://doi.org/10.1080/00045608.2012.657146