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Travel time to Nutrition Rehabilitation Centers: Measuring equity of access using road network data in Nandurbar district and implications for public health service design

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Abstract

Background

Maharashtra's Nandurbar district, a predominantly tribal and hilly region, faces high child undernutrition and access barriers to facility-based care. Families and providers cite distance, transport constraints, and terrain as major obstacles to nutritional rehabilitation center (NRC) use and follow-up. This study aimed to measure spatial access to NRCs and identify gaps in geographical coverage and accessibility in Nandurbar district in Maharashtra.

Methods

We conducted a district-wide drive-time analysis using Google road network data to estimate minutes to the nearest NRC for every village. Villages were classified into 30/60/90/120-minute driving bands and child burden. NRC facility and villages were mapped, and numbers of children with severe acute malnutrition (SAM) were obtained from a district-wide joint screening in April 2025. Numbers of children admitted to NRC were obtained from district health records.

Results

The mean drive time to the nearest NRC was 41 minutes (range: 2–228). The analysis was conducted for a sample of 2804 children with SAM across 952 villages. 19.2% of villages and 23.7% (665 children) of SAM cases were ≥ 60 minutes from an NRC; 4.4% of villages and 7.3% (205 children) of SAM cases were ≥ 90 minutes. Clusters of high SAM and long travel were concentrated in Akrani, Shahade, and Akkalkuwa. The admissions/SAM ratio varied widely—Akkalkuwa 0.37, Akrani 0.32, Nawapur 0.31, versus Shahade 0.11 and Taloda 0.09 (the latter with the highest SAM burden). The analysis highlighted villages where setting up treatment centers based at primary health centers and provision of referral transport could yield immediate gains.

Conclusions

Drive-time modeling reveals actionable geographic inequities in access to NRCs in Nandurbar. Travel time is one aspect of the challenges families face, as many people do not have access to vehicles or financial resources to pay for easy transport. Establishing additional treatment options at select PHCs in far–high-burden corridors, strengthening transport, and coordinating care at border areas of the district can reduce time-to-care for severely malnourished children.

Introduction

Persistent child malnutrition is a major public health challenge in India. Malnourishment in children has short- and long-term consequences, including adversely affected cognitive functioning and weakened immune system.[1] Child malnutrition is prevalent in Nandurbar district, Maharashtra, a predominantly tribal district with disproportionately poor child health outcomes (wasting, stunting, coverage of all basic vaccinations, and birth in a health facility). The National Family Health Survey (NFHS) 5 from 2019–2021 highlights the extent of undernutrition among children under five years in Nandurbar, finding 57% of children to be underweight.[2] Furthermore, NFHS-5 found 46% of children to be stunted, 31% to be wasted, and 13% to be severely wasted. These rates of undernutrition in the district are higher than the Maharashtra rates — 36% underweight, 35% stunted, 26% wasted, 11% severely wasted — and significantly higher than the national averages — 17% underweight, 36% stunted, 6% wasted. Nandurbar district also faces significant healthcare delivery challenges due to its remote geography, limited workforce, and residents' distrust of health care.[3], [4]

Government of Maharashtra protocols direct that children with severe acute malnutrition (SAM) should be admitted to community-based or facility-based care, based on the presence of health ailments, presence of bilateral pitting oedema, and an appetite test. Community-based care is conducted through Village Child Development Centers (VCDCs), which is a day-care treatment that includes supplemental food managed at Anganwadi Centers (AWCs) based in villages.[5], [6] For more serious cases, facility-based care is available at hospitals where children are admitted to Nutrition Rehabilitation Centers (NRCs) for inpatient stays.[7], [8]

In Nandurbar district, Anganwadi workers (AWWs) and NRC staff report that families of children with SAM cite distance and difficult terrain as barriers to NRC treatment. The authors have conducted interviews with NRC staff and health officials in Nandurbar. An important theme emerged that many children do not return for follow-up visits following the inpatient treatment due to the distance and travel time required to reach the NRC. Distance to facilities is a documented barrier to health care access, with prior studies finding distance to impact usage of health care services in India, including among older adults and for institutional delivery.[9], [10] This is also a significant factor for populations in rural India, where travel distance can impede health care access and nutrition service delivery.[11], [12] Access to NRCs in Nandurbar has not been previously measured. Beyond travel time, families in Nandurbar also face opportunity costs of inpatient treatment due to wage loss and the need to care for other children, a lack of trust in health care, and a lack of awareness of the importance of treatment for severe cases of SAM.

Using drive-time modeling, this study aims to measure access to NRC treatment in Nandurbar. Prior geospatial analysis has aimed to estimate travel-time, population coverage, and access to health care facilities in India — particularly in rural areas.[13], [14] This study uses village-level malnutrition screening data, NRC locations, road-network driving time, and NRC admission records to assess geographical access to facility-based malnutrition treatment across Nandurbar. The objectives of this analysis are to quantify percentages of villages and percentages of children under six years of age with SAM or moderate acute malnutrition (MAM) within 30/60/90/120 minutes of the nearest NRC; identify worst-access villages (high SAM burden and longest drive time); and

compare accessibility by Sub-District. Furthermore, this work aims to provide actionable recommendations to address the gaps in access identified in the analysis.

Methods

Data Source

This analysis uses data on the number of children with SAM or MAM by AWC and village collected during a malnutrition screening drive conducted in Nandurbar in April 2025. The screening drive was conducted through a joint screening initiative directed by the district administration. In joint screening, Integrated Child Development Scheme (ICDS) supervisors and Public Health Department (PHD) staff (Auxiliary Nurse Midwives (ANMs), staff nurses, Medical Officers (MOs)) from one block visit another block's villages and Anganwadi Centers (AWCs) to conduct growth monitoring, health checkup and triaging of the children with SAM. The Anganwadi workers and ASHAs remain at their base location to facilitate the caregivers' mobilization for bringing their children at the site of joint screening. Reshuffling of the staff is intended to maintain data quality and avoid collusion or bias.

The travel time analysis utilized the NRC locations and Google Road Network Data. Driving travel time was preferred over distance to account for realistic access, which is particularly important for the Nandurbar context given the mountainous terrain. The analysis used village-level shapefiles as the origin point for the driving time. Village-level shapefiles were created and validated by government officials in the district.

An additional analysis was conducted as a validation of the findings of the drive-time analysis using a one-year summary of the number of admissions at Nandurbar NRCs and the village of the child. The number of children admitted to the NRCs was divided by the number of SAM cases found in the joint screening to create a ratio of NRC admissions to SAM cases.

Variables

The two main variables of interest are numbers of children identified with SAM in each location, and the driving time in minutes to the nearest NRC location. The additional variable of numbers of admissions at Nandurbar NRCs was used for analysis.

Methodology

Village-level road accessibility to Nutrition Rehabilitation Centers (NRCs) was assessed across Nandurbar district using village boundary polygons as the spatial unit of analysis. A representative point for each village was generated by calculating the polygon centroid in GeoPandas, and the resulting latitude and longitude were used as the village origin. For each village, the geographically nearest NRC was identified by calculating geodesic distance to all available NRC coordinates within Nandurbar district. The NRC with the minimum geodesic distance was assigned to that village, and its name, coordinates and distance were retained in the analytical dataset. Only government NRCs were included, and private health facilities were not included.

Road-network driving time from each village centroid to its assigned NRC was then estimated using the Google Maps Platform routing service. The routing analysis was processed on 7 October 2025 with travel mode specified as driving. Village coordinates were provided as the origin and NRC coordinates as the destination. For successful routes, Google returned journey duration in seconds, which was converted to minutes and stored as the village-level driving-time measure. The implementation used the Google Distance Matrix endpoint with metric units and supported multiple village origins for a common NRC destination.

The processing workflow included basic geographical quality-control checks, including validation of latitude and longitude ranges and checks for potentially reversed coordinate pairs. API requests were rate-limited, and retry handling was implemented for unsuccessful or temporarily rate-limited requests. Live traffic conditions were not included; therefore, the derived measure represents modelled road-network driving time rather than real-time or traffic-adjusted travel time.

The resulting driving-time estimates were linked back to the village spatial dataset and summarised at village, sub-district and district levels. Accessibility was examined using predefined travel-time thresholds of approximately 30, 60, 90 and 120 minutes to describe geographical coverage and identify villages with relatively poor access to NRC services.

For the main analytical dataset, village-level accessibility measures were linked with malnutrition indicators from the April 2025 Nandurbar joint screening initiative to examine the spatial distribution of SAM and MAM burden in relation to NRC accessibility. A separate one-year summary of NRC admissions by village was also used to assess utilisation of NRC services in relation to geographical access.

Driving time was selected as the primary accessibility measure because it better reflects road-network access than straight-line distance in the mountainous terrain of Nandurbar. However, these estimates represent modelled geographical accessibility rather than observed household travel time. The analysis uses village centroids rather than individual household locations and therefore does not capture within-village variation in residence or road access. It also does not account for transport availability or cost, waiting or walking time, referral delays, household responsibilities, seasonal road disruption, or other barriers that may influence whether a caregiver is able to reach an NRC. Monsoon-related road-access limitations were not incorporated into the model.

We conducted the bivariate spatial clustering analysis using local indicators of spatial association (LISA) to identify clusters of village-level malnutrition burden associated with driving time to the nearest NRC.

Results

Summary Statistics

Throughout the district, the average driving time to the nearest NRC is 41 minutes, and the range is 2-228 minutes. Table 1 provides the sub-district and district summary of the SAM/MAM burden and driving time to nearest NRC. Shahade and Akrani have the highest average driving time to the nearest NRC. Distance to NRCs was also calculated. Shahade villages have the highest mean and median distance to the nearest NRC – 33.1 km and 31.9 km, respectively.

Table 1. Nandurbar: Per-Village Summary of SAM, MAM, Driving Time, and Distance

Nandurbar: Per-Village Summary of SAM, MAM, and Driving Time

Mean, median, and range by sub-district; includes district total

		SAM (children per village)			MAM (children per village)				Driving time to nearest NRC (min)		
Sub-District	Villages	Mean	Median	Range	Mean	Median	Range	Children Screened (0-6 years)	Mean	Median	Range
Akkalkuwa	193	3.3	3	0–19	16.4	13	0–72	28,786	31.6	27	3–144
Akrani	163	5.0	3	0–30	19.9	14	0–102	28,445	44.3	33	4–228
Nandurbar	154	2.2	2	0–14	11.6	9	0–52	19,660	32.5	30	5–66
Nawapur	163	1.4	1	0–17	8.0	6	0–49	14,657	31.5	32	4–60
Shahade	185	2.8	1	0–24	15.4	9	0–130	36,967	69.6	70	34–116
Talode	94	2.9	2	0–14	13.5	12	0–50	14,280	29.4	27	2–81
District (Total)	**952**	**2.9**	**2**	**0–30**	**14.3**	**10**	**0–130**	**142,795**	**41.1**	**35**	**2–228**

Overall, 19.2% of villages (Figure 1) and 23.7% of all children with SAM (Figure 2) are ≥ 60 minutes from an NRC; 4.4% of villages and 7.3% of children with SAM are ≥ 90 minutes. The villages more than 90 minutes driving distance from the nearest NRC can be identified as priority areas for potential child treatment centers (CTCs) or other community-based interventions for malnutrition treatment. The percentage of children with SAM and MAM that are beyond a 90-minute drive show the amount of burden that may be considered beyond reasonable reach. While not all children with SAM require NRC treatment, those that do are likely to delay or miss care due to distance.

The below maps display the results of the driving time analysis beside the map of village-level SAM burden. Three major clusters of inaccessibility in Akrani, Shahade, and Akkalkuwa lie on the borders of the districts — which prompts a need to understand whether populations in these villages are likely to seek care at health facilities in states across the border – Gujarat, Madhya Pradesh. An additional pocket of inaccessibility is located in the middle of the district at the border of Akrani and Taloda, where the villages also have a relatively high burden of SAM (Village Astamba is a 120-minute drive to the nearest NRC at SDH Taloda, and had 21 and 76 children with SAM and MAM, respectively). High-burden SAM and high driving time clusters are prime candidates for CTC and referral transport investments.

Bivariate LISA Analysis

A bivariate LISA analysis was conducted to identify spatial clusters of village-level malnutrition burden associated with the driving time to the nearest NRC. Villages were classified into four cluster types: high malnutrition–high neighbouring NRC driving time, low malnutrition–high neighbouring NRC driving time, low malnutrition–low neighbouring NRC driving time, and high malnutrition–low neighbouring NRC driving time; villages without statistically significant spatial association were classified as such.

The high malnutrition–high neighbouring NRC driving time category is the primary priority cluster, as it identifies where high malnutrition burden co-occurs with poor geographic NRC access. The map (Figure 4) shows priority clusters concentrated in parts of Akrani and Shahade, with additional smaller pockets in the district's Akkalkuwa area.

The LISA map (Figure 4) includes existing NRCs and the two proposed NRC locations overlaid to assess the alignment of the proposed service expansion with identified priority clusters. The proposed NRC sites at Toranmal and Shahada appear positioned near areas identified as high-priority clusters, supporting their consideration as locations for additional treatment capacity.

The drive-time analysis was used to identify the top 20 villages by SAM of the villages that are at least a 90-minute driving distance from the nearest NRC (Table 2). These villages can be considered the most urgent targets for outreach, transport assistance, or PHC-based CTC support.

Table 2. Top 20 Villages by SAM with Driving Time ≥ 90 min

Top 20 Villages by SAM with Driving Time ≥ 90 min					
Includes Village, Sub-District, SAM, MAM, Driving Time, and Nearest NRC Name					
Village	Sub-District	SAM	MAM	Driving Time (min)	NRC Name
Toranmal (june)	Akrani	30	102	140	SDH Dhadgaon
Astamba	Akrani	21	76	120	SDH Taloda
Phalai	Akrani	20	49	191	SDH Dhadgaon
Toranmal (New)	Akrani	19	64	147	SDH Dhadgaon
Langadi-bhavani	Shahade	19	84	100	SDH Taloda
Khadki	Akrani	18	58	166	SDH Dhadgaon
Kelapani	Akrani	17	54	110	SDH Dhadgaon
Udadya	Akrani	16	20	116	SDH Dhadgaon
Kundya	Akrani	16	31	112	SDH Dhadgaon
Nagziri	Shahade	15	69	100	SDH Dhadgaon
Kotbandhani	Shahade	15	48	99	SDH Dhadgaon
Ranipur	Shahade	14	76	90	SDH Dhadgaon
Ambapur	Shahade	13	20	94	SDH Dhadgaon
Ganor	Shahade	11	37	102	SDH Dhadgaon
Pimprani	Shahade	11	31	97	SDH Dhadgaon
Shahane	Shahade	10	38	92	SDH Taloda
Chandsaili	Shahade	7	10	91	SDH Taloda
Malgaon	Shahade	5	55	100	SDH Taloda
Sindidigar	Akrani	3	6	172	SDH Dhadgaon
Khaparkheda	Shahade	3	9	91	SDH Taloda

NRC Admission Numbers (April 2024 – March 2025)

When comparing the number of SAM cases found during the joint screening against the admission numbers in Nandurbar NRCs from one year (Table 3) – we find the highest admissions to SAM ratio in Taloda (0.44), Akkalkuwa (0.37), Akrani (0.32) and Nawapur (0.31). The lowest ratios are in Shahade (0.11) and Nandurbar (0.22). The priority gaps highlighted here are that Shahade and Nandurbar show the largest shortfall (high SAM, low admission ratios).

The admissions list also shows that in this year-long period, only two children from Astamba village in Akrani sub-district were admitted at NRCs in Nandurbar. Astamba is ranked second in the list of high-burden villages, with 21 children with SAM, 76 children with MAM, and a 120-minute drive to the nearest NRC in Taloda.

Table 3. Nandurbar: SAM and NRC Admission Numbers

Nandurbar: SAM and NRC Admission Numbers				
Number of children with SAM at joint screening, annual NRC admissions				
Sub-District	Villages	Total SAM	NRC Admissions	Admission to SAM Ratio
Akkalkuwa	193	637	235	0.37
Akrani	163	813	259	0.32
Nandurbar	154	340	76	0.22
Nawapur	163	226	70	0.31
Shahade	185	515	57	0.11
Taloda	94	273	120	0.44
District (Total)	**952**	**2,804**	**827 (including outside NDB)**	**0.29**

Discussion

India faces high rates of childhood malnutrition, particularly in rural and tribal-dominated regions of the country. One important tool in the efforts to address childhood malnutrition and reduce deaths due to malnutrition is inpatient treatment provided at health care facilities, including specialized NRCs. This district-wide drive-time analysis shows that access to NRCs is uneven in Nandurbar, with meaningful pockets of high burden and long travel times. Although the average drive time is 41 minutes (range: 2–228), 19.2% of villages are, and 23.7% of all children with SAM live ≥ 60 minutes from an NRC. Furthermore, 4.4% of villages and 7.3% of children with SAM are ≥ 90 minutes away. These figures suggest that a substantial share of vulnerable children in Nandurbar may face delay in seeking treatment, incomplete adherence, or missed care. The analysis finds geographic inequities concentrated in Akrani, Shahade, and Akkalkuwa, including border-adjacent corridors. The "Top 20 villages" list—defined by highest SAM among villages ≥ 90 minutes—provides a concrete, near-term target set for PHC-based CTCs, transport assistance, and mobile outreach. Shahade and Nandurbar districts have the lowest admission-to-SAM ratios, (0.11 and 0.22, respectively), indicating severe conversion-to-care gaps. In contrast, Akkalkuwa (0.37) and Akrani (0.32) appear to convert more SAM cases to NRC admissions, suggesting that local practices and referral pathways in those areas could be adapted in lagging blocks.

This study provides actionable data on spatial accessibility of NRCs in Nandurbar district, an area with high prevalence of acute malnutrition among children under six years. Integrating village-level data across the district with road-network drive time provides information on practical accessibility. Furthermore, using malnutrition data from a joint screening exercise provides high-quality data of malnutrition burden in the district, a metric that has been found to differ across sources.[15] Limitations of this analysis include travel-time modeling assumptions that may not reflect actual conditions. Seasonality, road closures, and vehicle type will impact travel time, potentially resulting in travel times that exceed those estimated in the analysis. Additionally, the driving time was estimated using village centroids and thus does not capture intra-village variation in travel time. As explained above, the six NRC locations used in the analysis may not represent all care options available if some families choose to obtain care at facilities outside of the district. Furthermore, actual or perceived efficacy of NRC treatment may also influence care-seeking behavior.[16], [17], [18] Burden measurement of SAM/MAM counts are a cross-sectional estimate from a measurement screening conducted in April 2025, and may not represent the burden over time and may reflect trends related to seasonal migration patterns. Similarly, the NRC admissions counts are from one year of NRC admissions and may not accurately represent admissions patterns for a longer period.

The study is consistent with other geographical accessibility analyses using travel time to describe access to health facilities. Previous studies have similarly generated isochrones of travel time by car from health care sites.[13], [14] This study provides additional insight by linking access directly with the district's village-level malnutrition burden of SAM, rather than measuring accessibility for the general population. Furthermore, we validated the findings of accessibility against previous utilization levels of NRC. The study also produces operational outputs for actions the district can pursue to address the identified gaps. Unlike prior studies, this analysis is specific to one district and the service type of NRCs.

While travel time is an important structural barrier to NRC access in Nandurbar, it is unlikely to be the only determinant of care-seeking. Household decisions to seek facility-based treatment for severe acute malnutrition may also be shaped by demographic characteristics, such as socioeconomic and education background, and opportunity costs, including lost wages and missed care responsibilities for other children.[19], [20] Families may weigh NRC admission against other available options, including treatment closer to home through VCDCs, informal local care, or private doctors. This driving time analysis cannot capture these other aspects. Thus, low admission rates in remote areas should not be interpreted as a function of distance or driving time alone, but rather as the outcome of interacting geographic, social, and household-level factors. The sub-district summaries highlight wide differences in median driving time and distance (e.g., Shahade's higher mean/median distance) that may reflect structural barriers (road quality, terrain, facility placement). The paired maps (Figs. 3a. drive-time and 3b. SAM burden) underscore co-located risk: high SAM and long travel in the same places. The bivariate LISA analysis helps distinguish between areas where poor access is isolated and areas where high malnutrition burden and poor NRC accessibility are spatially concentrated, which allows for the identification of more appropriate targets for new NRCs, PHC-based treatment centres, referral transport, or mobile outreach. District leadership in Nandurbar has used this analysis to propose two new NRC sites, the Toranmal and Shahada NRCs shown in the LISA analysis map (Fig. 4). As seen in the map, the Toranmal site falls in a high malnutrition–high neighbouring NRC driving time cluster, and the Shahada site falls in a low malnutrition–high neighbouring NRC driving time cluster. The optimal location of the NRC must also consider resource constraints, limiting the intra-block location options. For the Shahada NRC case, the district leadership will use the existing Rural Hospital in Shahada to house the NRC facility. The analysis additionally prompts investigation for the pocket of low malnutrition–high neighbouring NRC driving time cluster in Akkalkuwa, to understand the usage of the NRC and potential barriers unique to that area.

The concentration of high driving time areas across border-adjacent corridors motivates questions of whether families in border villages utilize care outside of the district. Given the cross-border proximity (states of Gujarat and Madhya Pradesh), some remote villages may naturally seek care outside the district, which can decrease observed admissions locally. As such, the pattern of low access in border-adjacent areas prompts the need for additional work to understand whether those in border-adjacent areas seek care from facilities outside of the district and in neighboring states. Future iterations should incorporate cross-border service mapping and seasonal scenarios to deepen the understanding of access for facility-based child malnutrition treatment in Nandurbar. Finally, the results of this study have motivated potential application and recommendations detailed in the next section.

Recommendations

The results of these analyses were shared with public health and nutrition officials in Nandurbar through district meetings. Government officials used the findings to inform recommendations for the district's NRC sites, including a proposal to create a new NRC in the Shahade sub-district. Additionally, the public health and nutrition officials suggested areas, based on the burden and driving time maps, where CTCs can be launched at select Primary Health Centers (PHCs). These approaches embody targeted responses that are efficient: focusing on high-burden villages in far-from-NRC corridors.

Further potential action points beyond the NRC site proposals include validating the results on the ground, strengthening referral transport, conducting mobile outreach, establishing a monitoring and micro-targeting system, and improving cross-border coordination.

Validating the results in high-burden villages that are far from NRCs could help to understand NRC referral, transport, and admission practices and trends. For example, in Toranmal, it would be useful to understand whether children are able to receive care like NRC services through the government's Rural Hospital. Qualitative work could confirm whether low access is primarily driven by travel barriers or by other factors, such as local care-seeking preferences or the availability of alternative services.

Providing transport options, such as dedicated vehicle days and on-call transport, for villages located 60 or 90 minutes or more from an NRC could reduce delays in reaching NRCs, increase referral completion, and improve admission among children from the farthest villages. Mobile outreach could also be conducted in low-access, high-burden corridors to provide screening, immediate referral, and potential transport. This could improve the early identification and triaging of children in underserved corridors, reduce missed referrals, and increase the number of children who enter treatment before complications worsen.

Monitoring and micro-targeting could be strengthened through a monthly review of villages in the higher driving-time bands of 61–90, 91–120, and more than 120 minutes, particularly those with a high SAM burden. These villages could be monitored as a watchlist of high-risk locations. This approach could improve the efficiency of district action by allowing frontline teams and administrators to focus regularly on the highest-risk villages and track whether access gaps are narrowing over time.

Cross-border coordination by working with neighboring states could help to identify facilities that are closer in travel time than in-district NRCs for families living in border-adjacent areas and if there are state-specific resources that affect migrants who are crossing borders. With data-sharing agreements, this could expand the practical treatment options available to families, reduce travel burden, and provide a more accurate picture of where children from Nandurbar are receiving care.

Conclusion

This drive-time analysis documents access to NRCs in Nandurbar and highlights areas for improvement: nearly a quarter of children with SAM live ≥ 60 minutes from care, and there exist high-burden, remote clusters within the district. A comparison of priority clusters (villages with highest drive time and highest burden of SAM cases) with NRC admissions numbers also show lower rates of treatment for the two blocks with highest driving time (Shahade and Taloda). The district's usage of this data has led to the proposal of child treatment centers at select PHCs and of new NRCs to be added in high-burden areas with low access to NRCs. Instituting child treatment centers at select PHCs, coupled with referral transport and mobile outreach, could meaningfully reduce travel-time barriers for the most at-risk children. Sub-district differences and the "Top 20 villages" list provide operational starting points.

This analysis provides an example of how existing data sources can be used to generate actionable insights for health and nutrition officials. Beyond Nandurbar, this approach could be replicated in other districts to identify underserved clusters, compare access across blocks, and guide decisions on where to strengthen referral and transport systems, locate child treatment centers, or expand facility-based services. Furthermore, this methodology can be applied to other types of health services using locations of treatment-specific facilities and burden of relevant conditions in the population. With these insights, district administrators can more precisely direct resources and efforts to the geographies and populations that are most vulnerable.

Abbreviations

NRC: Nutrition Rehabilitation Center

MAM: moderate acute malnutrition

SAM: severe acute malnutrition

VCDC: Village Child Development Center

ICDS: Integrated Child Development Scheme

PHD: Public Health Department

ANM: Auxiliary Nurse Midwive

MO: Medical Officer

AWC: Anganwadi Centers

Declarations

Ethics approval and consent to participate

Patients and/or the public were not involved in the design, conduct, reporting, or dissemination plans of this research.

Consent for publication

Not applicable

Availability of data and materials

A separate public-use geospatial dataset has been prepared for open-source/public dissemination. To protect sensitive government health information, all village-level health, anthropometry, SAM/MAM, referral, admission, mortality and other program-related variables have been removed from the public file. The public dataset contains only the village identifiers and geography required for spatial reference, together with NRC accessibility variables such as the assigned NRC, NRC coordinates, distance to NRC and estimated driving time. The restricted analytical dataset containing health and program indicators will therefore remain separate from the public accessibility dataset.

Competing interests

None declared.

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Authors' contributions

S.K., R.N., and M.S. conceptualized the study. A.B. curated the data, and S.M. conducted the spatial analysis. S.K. and S.M. wrote the main manuscript text. S.K., R.N., S.M., D.S., and R.J. reviewed and edited the manuscript. All authors reviewed and approved the final manuscript.

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Figures

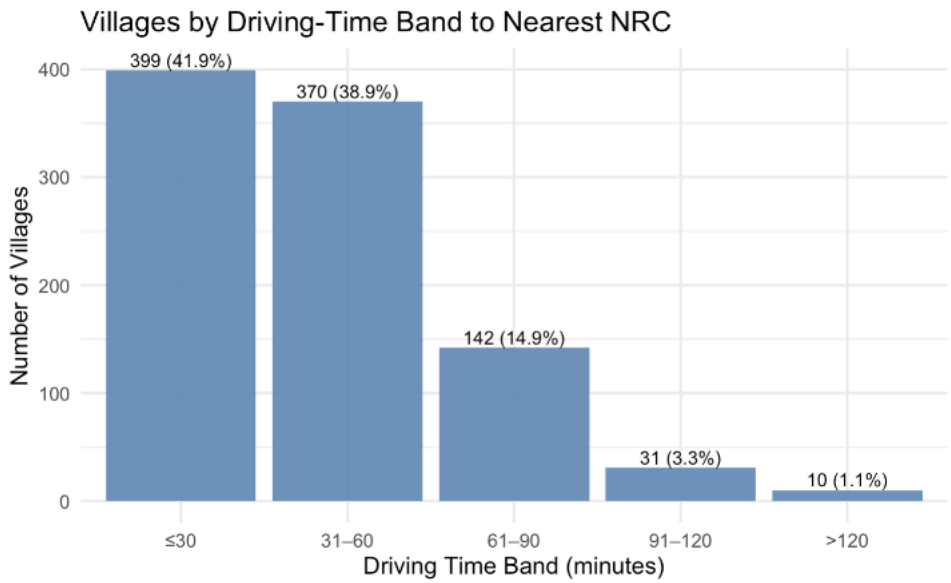


Figure 1

Villages by Driving-Time Band to Nearest NRC

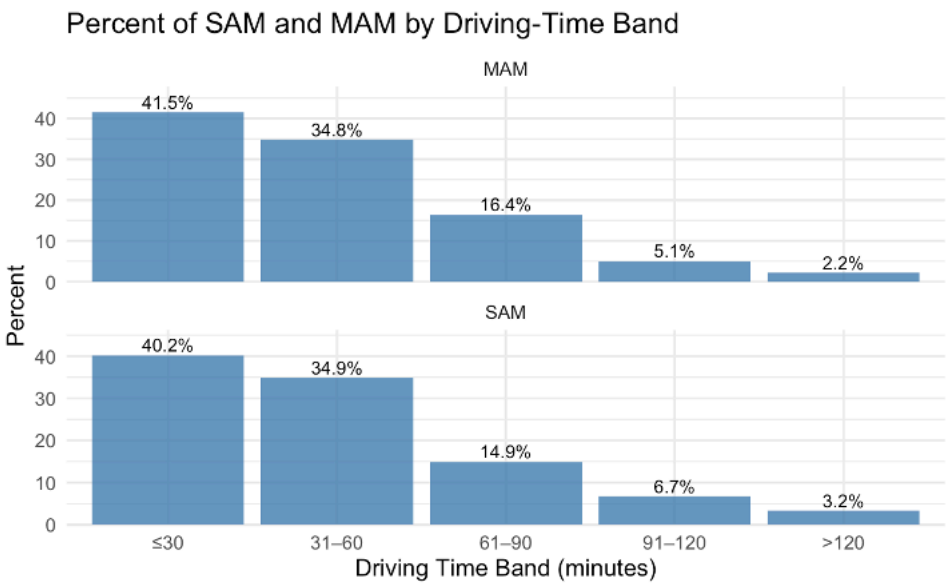


Figure 2

Percent of Children with MAM, SAM by Driving-Time Band to Nearest NRC

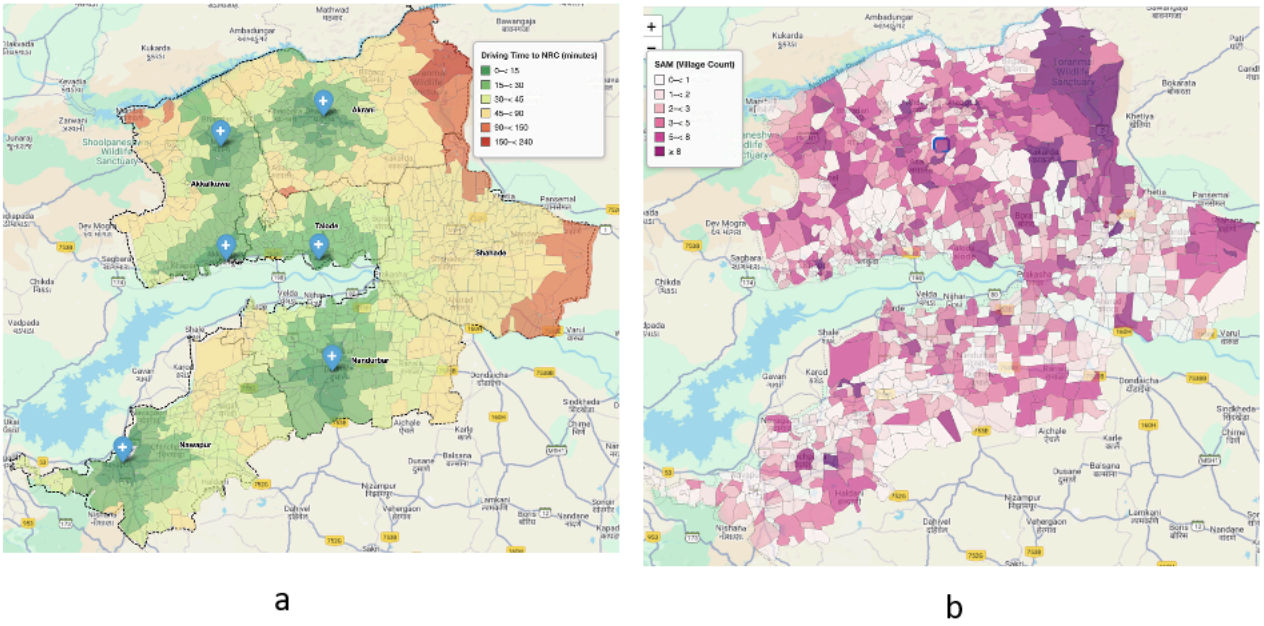


Figure 3

a. Map of Driving Time to NRC

b. SAM Burden in Nandurbar

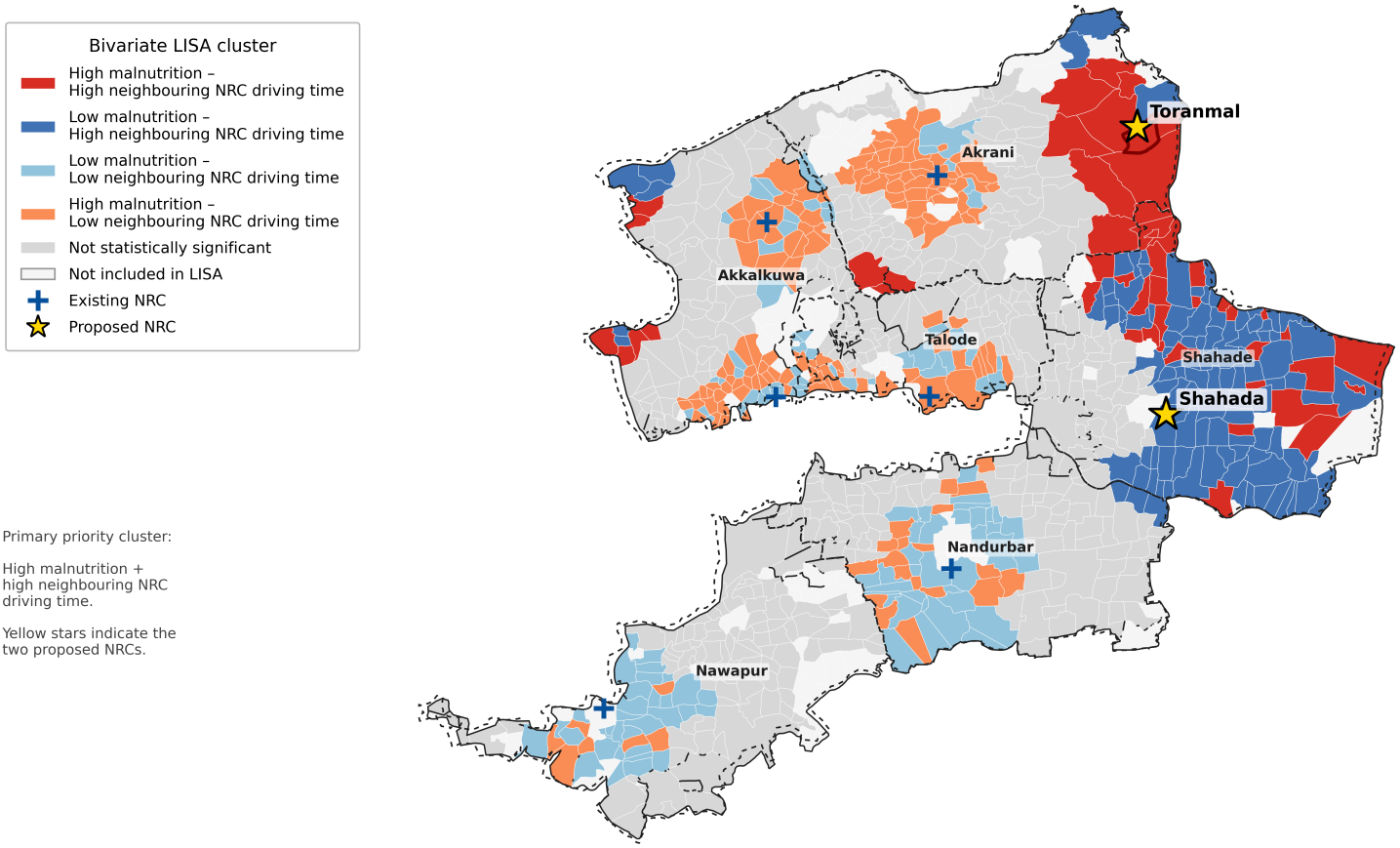


Figure 4

Bivariate Local Moran's I: Malnutrition Burden and NRC Accessibility, Nandurbar District