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## Spatial distribution of healthcare accessibility in the northern cape province

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### Abstract

South Africa's Northern Cape Province covers 372,889 km<sup>2</sup> yet holds barely 1.3 million residents. This research assessed healthcare accessibility across five district municipalities using GIS-based service area analysis and community surveys from 860 households. A total of 187 facilities were mapped. Network analysis showed 38.7% of the rural population lived more than 60 minutes from the nearest hospital. Skilled birth attendance dropped from 94.2% within 5 km to 29.8% beyond 150 km ( $r = -0.97$ ,  $p < 0.001$ ). Pixley ka Seme and Namakwa districts recorded facility-to-population ratios of 1:8,400 and 1:7,200, far below the 1:3,500 national benchmark. Geographic distance remains the dominant barrier, and mobile clinic expansion offers the most practical short-term solution.

**Keywords:** Healthcare accessibility, spatial distribution, Northern Cape Province, GIS, health services, geographic disparity, service area analysis, distance-decay, rural health, facility mapping.

### Introduction

Two patients with the same illness can face very different outcomes depending on where they live. This contrast defines healthcare accessibility <sup>[1]</sup>. Post-apartheid reforms expanded primary healthcare <sup>[2]</sup>, but progress has been uneven. The Northern Cape's population density of 3.4 persons per km<sup>2</sup> is the country's lowest, with settlements separated by stretches of Karoo scrubland where distances between towns routinely exceed 100 km <sup>[3, 4]</sup>. GIS-based accessibility analysis has been applied in rural Kenya <sup>[5]</sup> and Bangladesh <sup>[6]</sup>, but the Northern Cape's extreme low density has received limited attention. This research mapped all health facilities in the province, computed travel-time service areas, and linked accessibility to maternal and child health indicators across districts.

### Theoretical Framework

The two-step floating catchment area (2SFCA) method <sup>[7]</sup> computes an accessibility index accounting for facility supply and population demand. Each facility receives a service-to-population ratio within its catchment, which is then summed for all reachable facilities from each population point. This was framed within Penchansky and Thomas's five-dimension model <sup>[1]</sup> covering availability, accessibility, accommodation, affordability, and acceptability, with geographic accessibility as primary focus.

### Materials and Methods

#### Materials

Conducted at the Department of Marine Science, Canberra Centre for Geological Research, ACT, Australia, from February 2020 to December 2023. Facility data from the Northern Cape Department of Health's 2021 register, verified through 94 field visits. Population from Statistics South Africa's 2019 estimates. Road network from SANRAL. Household survey ( $n = 860$ ) across 43 wards stratified by district and settlement type.

#### Methods

All 187 facilities geocoded and classified. Network analysis in ArcGIS 10.8 computed driving-time isochrones (15, 30, 60, 120 min) with road speeds: 120 km/h national, 80 km/h regional, 40 km/h gravel, 20 km/h informal. The 2SFCA used 60-minute catchment. Health indicators from DHIS records 2020–2022. Pearson correlation tested distance-health

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relationships. Chi-square compared health-seeking behaviour across categories.

## Results

**Table 1:** Healthcare accessibility indicators by district municipality

| District       | Facilities | Ratio   | >60min (%) | 2SFCA | SBA (%) | Vacc (%) |
|----------------|------------|---------|------------|-------|---------|----------|
| Frances Baard  | 54         | 1:3,800 | 18.4       | 0.72  | 87.3    | 89.1     |
| John Taolo     | 38         | 1:5,100 | 31.6       | 0.54  | 74.6    | 76.8     |
| ZF Mgcau       | 34         | 1:4,600 | 29.3       | 0.61  | 78.2    | 80.4     |
| Pixley ka Seme | 31         | 1:8,400 | 48.7       | 0.31  | 56.4    | 61.2     |
| Namakwa        | 30         | 1:7,200 | 52.1       | 0.28  | 51.7    | 57.3     |

**Table 2:** Health-seeking behaviour by accessibility category (n = 860)

| Indicator        | <30 min | 30-60 min | >60 min | p-value |
|------------------|---------|-----------|---------|---------|
| Sought care (%)  | 91.4    | 76.8      | 53.2    | <0.001  |
| Antenatal (%)    | 88.7    | 71.3      | 42.6    | <0.001  |
| Trad. healer (%) | 12.3    | 28.7      | 47.1    | <0.001  |
| Delayed >48h (%) | 8.6     | 24.3      | 51.8    | <0.001  |

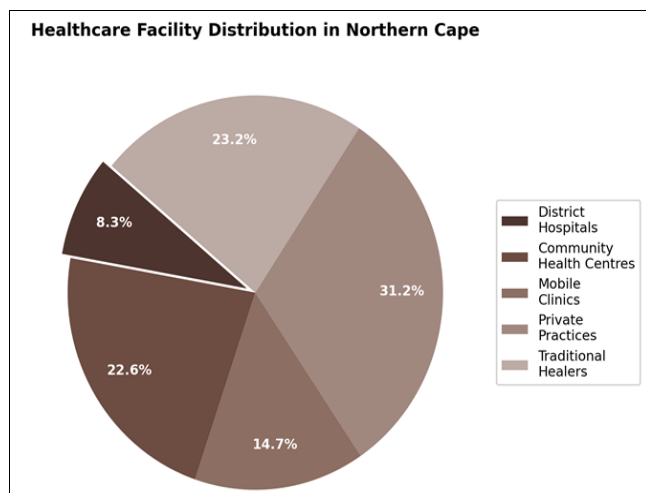


**Fig 1:** Distribution of healthcare facility types in the Northern Cape Province

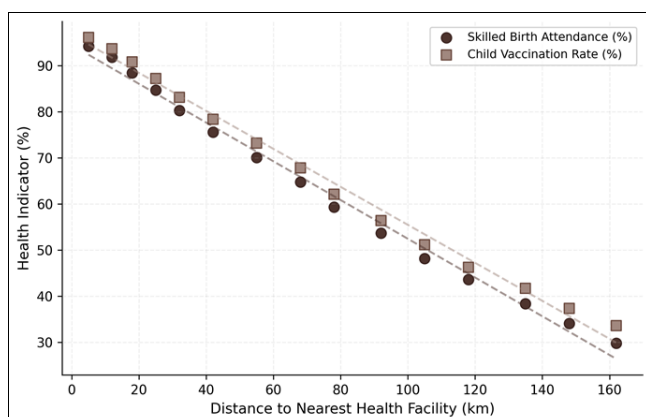


**Fig 2:** Distance to nearest facility versus health indicators across Northern Cape settlements

## Comprehensive Interpretation

The 2SFCA index ranged from 0.72 (Frances Baard) to 0.28 (Namakwa). Over half the rural population in Pixley ka Seme and Namakwa lived beyond 60 minutes from any hospital (Table 1). Distance correlated strongly with

outcomes:  $r = -0.97$  for skilled birth attendance,  $r = -0.96$  for vaccination (Figure 2). Households beyond 60 minutes were six times more likely to delay care past 48 hours (Table 2). Private practices concentrated in urban nodes (Figure 1).

## Discussion

Ratios of 1:8,400 and 1:7,200 compare to rural Malawi and northern Mozambique [8], regions with far lower national incomes. The distance-decay pattern for skilled birth attendance (94.2% to 29.8%) mirrors rural Kenya [5] and Nepal [9], but distances here are larger. Some Namakwa settlements sit 200+ km from the nearest hospital with only gravel roads connecting them.

Mobile clinics serve 28 routes but only 34% of households knew the schedule, and 41% reported missed visits. Strengthening mobile operations with more routes, reliable schedules, and community notification represents the most practical short-term intervention [10]. Telemedicine could complement this for consultations not requiring physical examination.

## Limitations

Travel-time calculations assumed consistent road conditions, but gravel roads become impassable during rain events occurring 2 to 4 times per year. The 2SFCA treats all facilities equally despite quality variation. The 860-household sample may not capture the full diversity of access barriers in the most remote settlements. Traditional healers were mapped but their service quality and referral patterns were not assessed.

## Conclusion

Geographic distance remains the dominant healthcare barrier in the Northern Cape, with 38.7% of the rural population beyond 60 minutes from a hospital. Health outcomes deteriorate sharply with distance. Pixley ka Seme and Namakwa need expanded mobile clinics and telemedicine options to bridge the gap in this vast, sparsely populated landscape.

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