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Type 1 Diabetes Care Access and Cost: A Geospatial Study in Ghana, Peru, and Nepal

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Abstract

Type 1 diabetes poses a distinct challenge to health systems due to its low prevalence and need for continuous access to insulin and care. This study aims to model the geographic accessibility to centralised versus decentralised Type 1 diabetes (T1D) services, and the implications for the population. Two care models for T1D were compared: centralised, where care is provided mostly at large hospitals, and decentralised care, involving an annual visit to a large hospital with routine care provided locally at smaller facilities. Geospatial accessibility and expense analyses were conducted for Ghana, Nepal, and Peru, to assess access to care and likely associated financial impact. Specialised, large hospitals provided > 82%, 35%, and > 72% population coverage within two hours' travel time for Ghana, Peru, and Nepal, respectively. Smaller hospitals covered about 92%, 50%, and 44% of the population within one hour. Annual per-person costs were highest in Peru (USD 1,280) and lowest in Nepal (USD 499), largely due to treatment costs. Travel-related costs per person were lowest in Ghana and highest in Peru. Travel-related costs per person were lowest in Ghana (about USD 14) and highest in Peru (approximately USD 354).

Geographical factors critically influence the economic burden of T1D. The distribution of facilities, characteristics of the terrain, and distances involved, strongly influenced the accessibility and costs for T1D care. This emphasizes the necessity for country-specific geospatial planning to achieve equitable care and the World Health Organization Global Diabetes coverage targets.

1. Introduction

Globally, about 9.5 million people were living with T1D as of 2025[1]. T1D is a lifelong condition that requires daily insulin, glucose monitoring, and regular medical support. However, many people in low- and middle-income countries (LMICs) face significant barriers to accessing these essential resources[2–4]. The barriers are not only due to the cost of insulin and care, but also the expenses and time required to physically reach large health care facilities[2,5]. This centralisation of insulin supply and diabetes management restricts access to care for rural and marginalised populations, who often have to travel long distances to receive appropriate treatment, education, and support. In high-income countries, some studies have found that travel time and distance, for certain conditions including diabetes, can affect health-related outcomes[6]. The high costs associated with travelling long distances can be prohibitive, in addition to the potential loss of income resulting from time away from work[7]. Even in countries where insulin is provided at low or no cost through public programmes, people living far from urban centres have to incur significant travel costs to reach hospitals and often pay out of pocket for supplies[3,8,9].

Given the centralisation of T1D services in many LMICs[9,10], there have been calls for and multiple examples of decentralisation[11,12]. Although several studies in LMICs have examined the economic burden of diabetes, the focus has been on the cost of insulin and associated medical supplies[2,13–16], rather than on physical accessibility and related transport costs, which have predominantly been studied

in high-income countries[17–20]. A recent scoping review analysing GIS mapping of T1D in children, confirmed this after finding only two out of 17 studies to address accessibility to health services, with all studies being conducted in high-income countries[21].

This study aims to investigate and quantify the costs associated with centralised and decentralised models of T1D care at the national level in three LMICs, focusing on geographical accessibility to care and treatment costs. The study adopts the person perspective, as individuals are directly affected by geographic barriers and bear most expenses such as travel, lost labour, and often consumables[2,3].

2. Methods

Two service delivery strategies for people with T1D were compared. The first is 'centralised care', in which people travel from across the country to a limited number of large or very large hospitals, often located in capital cities or major secondary cities. The second strategy is 'decentralised care', where people with diabetes have only one appointment per year in the very large hospitals, while for the rest of the year they attend smaller hospitals, which are more widely distributed across the country, for follow-up care.

For this analysis, we selected three LMICs from different continents to represent diverse geographical settings and health system structures. This selection was strategically informed by the significant challenges in obtaining high-quality data on health facilities providing large T1D care services and determining their precise geographical coordinates. Therefore, countries with established partnerships with local experts and previous research experience, which ensure data reliability and contextual understanding, were prioritized.

2.1. Setting

Ghana is a small to medium-sized country (239,567 km²) with a relatively well-distributed network of tertiary and secondary level hospitals and an extensive network of primary level health facilities over a rather flat landscape. The Ghanaian health system is divided into four main levels: regional, district, sub-district, and community level, with regional and teaching hospitals offering specialised treatment. Peru is a medium to large-size country (1,285,215 km²) with three distinct geographical zones: the Pacific coast, the Andes, and the Amazon basin. These zones strongly influence access to hospitals, which are mainly located on the coast. The Peruvian healthcare system consists of four sub-systems: the Ministry of Health, Social Security, Police and Armed Forces, and the Private Sector. The majority of the population receives care through the Ministry of Health facilities (61%) or Social Security (20%)[22]. For this study, we have focused on the institutions of the Ministry of Health. In Peru, people with T1D who use Ministry of Health facilities are mainly cared for in one of the two national specialised paediatric care centres, both located in the capital, Lima[23]. Nepal is a small country (147,516 km²) with three geographical zones – Terai, Hilly, and Mountains – where mobility from south to north becomes increasingly difficult (see Fig. 3 in Supplementary information). The Nepalese health system comprises a public sector, overseen

by the Ministry of Health and Population, and a substantial private sector, particularly in urban areas. The public system was divided into three levels: federal, provincial, and local, and services are delivered through a network of health facilities, ranging from local health posts and primary health care centres at the municipal level to provincial hospitals and central tertiary hospitals[24]. Additional information included in the Supplementary information.

2.2. Data sources and preparation

All geospatial and expense analyses are based on the population expected to be affected by T1D in each country. However, as subnational distributions of this target population are unknown, we assumed a proportional distribution of prevalence across the general population. Using prevalence estimates from the 2024 T1D Index (Gregory v2.0 model)[25], we derived a scaling factor and applied it to adjust all relevant results. For Ghana, Peru, and Nepal, there are estimated to be 11,414; 6,168; and 17,131 people with T1D, respectively, out of total populations of about 30.7, 32, and 29.2 million inhabitants[25,26].

2.2.1. Geospatial data:

The preparation, validation, and post-processing of the geospatial data were carried out in QGIS (v3.40.8)[27] and R (v4.5.1)[28]. All raster layers were merged (if tiled), resampled, aligned, and clipped. Both the raster and vector data were then projected into the most appropriate metric coordinate system for each country. For each country, we assembled the locations of all healthcare facilities associated with T1D treatment. We also compiled country-specific travel scenarios, that is, on- and off-road modes of transport and travel speeds used by the population to reach the nearest healthcare facility. Below, we summarize the types of healthcare facilities included and the travel scenario for each country. Further details are provided in the Supplementary information.

Ghana

The data types and sources are described in Table 1 (Supplementary information). The selection of health facilities providing specialised (large hospitals) and general (smaller hospitals) T1D care was guided by local experts from the WHO country office and the Ghana Health Service (GHS). In Ghana, the distinction between specialised and general T1D service providers follows the standard categorization of hospitals, with large hospitals classified as Regional, Teaching, and University hospitals, and general hospitals classified as District hospitals. Local experts confirmed that private clinics are unaffordable for most people; therefore, they were excluded from our analysis. The travel scenario was obtained from GHS experts in June 2024 during a national capacity-building workshop on accessibility modelling (Supplementary information).

Peru

The data types and sources are described in the Supplementary information. For Peru, we applied a multi-zone travel scenario to account for the fact that mobility in some urban areas of the country is

significantly slower than in rural areas[29]. The baseline travel speed scenario was based on Carrasco-Escobar et al.[30]. The detailed scenario is provided in the Supplementary information. The hospitals considered were selected by the co-authors including only public facilities and excluding military and private facilities.

Nepal

The data types and sources for Nepal are described in the Supplementary information. For the selection of health facilities, we first analysed and filtered the Nepal Demographic and Health Survey (DHS) Service Provision Assessment (SPA) 2021, which included 1,626 facilities and 2,477 variables, retaining 11 variables including administrative area codes and available diabetes management indicators. We consulted local experts to validate the facilities operating as specialised or general care providers. People often visit some large private teaching hospitals because they are not much more expensive than public ones (with some exceptions)[31]. Therefore, we included some private teaching hospitals where diabetologists and/or specialised endocrinologists work.

For Nepal, we also developed a multi-zone travel scenario to better reflect the speed of mobility in the three different geographical zones of Nepal (the Terai, the Hilly zone, and the Mountains). The final speed scenario was generated as an average from the expert-based scenarios of Ochoa et al.[32] for the Terai, which include three vehicle types for the dry season, and from two separate surveys conducted during a maternal health workshop led by the Nepalese Ministry of Health in 2025, considering the three geographical regions. These data sources were averaged to standardize possible divergences of opinion and vehicle types.

2.2.2. Cost factors

The cost analysis focused on the most significant expenses for people with type 1 diabetes: consumables, medical visits, tests, transport, and lost income from time spent accessing care. Costs were summarized using median values to reduce outlier effects. The consumables evaluated were human insulin, syringes, glucose test strips, glucometers, and lancets. For insulin, we considered the cost of a 10 ml vial (100 IU/ml) per month. For syringes and lancets, we considered the cost of 30 units per month. For test strips, we considered the cost of 100 strips per month needed to measure blood glucose levels (about 3 tests/day). Assumptions reflect constrained settings, and reuse of some items within a day. Transport costs were estimated based on vehicle type and travel distance/time (excluding tourist transport). Lost labour income was calculated using minimum monthly wages, assuming 26 working days per month.

2.3. Geospatial accessibility modelling

To model population travel time to healthcare, we used the *Accessibility analysis* module of AccessMod v5.9 software[33]. AccessMod combines data on the road network, land cover, and topography with a travel scenario to estimate travel time from any location in the country to the nearest service location (in our case, T1D care facilities) using a least-cost path algorithm. Details of this procedure are available

elsewhere[34]. These results were used to calculate the weighted travel time by multiplying the prevalent population by their specific travel times to obtain an accurate total travel time for the affected population. Additionally, we used the Geographic coverage analysis module, which allows the establishment of hospitals' areas of coverage, i.e., the areas around specific health facilities where the T1D prevalent population can reach the hospital within a certain maximum travel time. The maximum travel time is two hours to large hospitals and one hour to smaller hospitals. These thresholds are based on international benchmarks for accessibility to health services[35], national expected population accessibility times to health care, and analyses on the acceptance of travel time to treatment[36]. Finally, we used AccessMod's Zonal statistics module to determine the percentage of the T1D prevalent population that can reach services within thresholds ranging from one to twelve hours.

2.4. Cost analysis

The cost analysis was limited to one year and divided into months as a standard unit of time to account for the temporality of disease management. Cost information was obtained from multiple sources, including existing literature[37–42], local expert advice from physicians and health professionals, and searches in two large language models (LLMs): ChatGPT and Perplexity AI, using the 'DeepResearch' search mode[43,44]. LLMs were used as a faster method to explore the web and obtain multiple results simultaneously. Examples of the prompts used are provided in the Supplementary information. Each reference link provided by the LLMs was visited and validated as real[45]. We found no discrepancies between the AI reported values and the visited websites. For Peru, we also used the pricelist brochure (*el tarifario*)[46] from the Peruvian Ministry of Health. This indicated the 2024 costs of outpatient consultation and management cost at third level hospitals (~ USD 4.2) and the advice on diabetes, as well as support monitoring (~ USD 1.2).

Costs found in local currency and were converted to nominal USD at the rates of January 2025 (USD 1 ~ GHS 15.35, PEN 3.76, NRP137). All values used the median to mitigate the effect of outliers. In addition to the median, we also calculated the interquartile ranges (Q1 and Q3), but only for the travel costs per hour, for which we had more than eight or nine values.

To calculate the total annual costs for both the centralised and decentralised models, we used the following equations, using the centralised service delivery model (M1) with the median travel cost as an example:

$$M1_{med} = \mathrm{Prev}\backslash: (TM1_{med} + FixC) + LWM1$$

In the first term, Prev is the T1D prevalence in 2024, $TM1_{med}$ is the combined annual travel costs, and $FixC$ represents the fixed costs incurred by each person.

$TM1_{med}$ is further decomposed as follows:

$$TM1_{med} = 2WTT_c \times\ CT_{med} \times\ 12$$

where WTT_c is the weighted one-way average travel time to the nearest facility (in hours), i.e., the travel time based on the specific location and number of the prevalent population. This term is doubled to account for a return journey. CT_{med} is the median travel cost per hour of different types of motorized travel (in USD). The total is multiplied by 12 expected trips per year. Other costs associated with travelling to large or small facilities, such as accommodation and food were not included. However, if the analysis is done in large countries, these expenses might be important and the modeller ought to find a way to standardise that value to add it to the model.

The fixed costs ($FixC$) are decomposed as follows:

$$FixC = CSA + (SGA \times\ 11) + CSE + CGl + (CIn \times\ 12) +$$

$$(CSt \times\ 12) + (CLt \times\ 12) + (CSy \times\ 12)$$

We assumed 12 annual medical appointments. Of these, CSA is the cost in USD of one specialised medical appointment per year, and SGA is the cost of 11 control medical appointments at smaller hospitals with a doctor or professional nurse (one per month). CSE is the cost of a specialised exam or test once a year. CGl is the cost of a glucometer once a year. CIn is the average monthly cost of insulin multiplied by 12 months. CSt, CLt, and CSy represent the monthly costs of glucose strips, lancets, and syringes, respectively. Fixed costs are the same for both centralised and decentralised models because we assumed that people with T1D, even if they only need to visit a centralised facility for check-ups, are more likely to be seen by general practitioners and nurses than by specialists. It was not possible to distinguish between the price of a general practitioner appointment in a large facility and a small facility.

Finally, the third term, $LWM1$, is the total annual cost incurred due to lost work caused by travel to medical appointments.

$$LWM1 = CLW \times\ 12 \times\ T1D_ResPop_M1$$

Its elements represent the expected cost of one day of lost work (CLW), multiplied by 12 expected medical appointments per year, and by the residual population for the analysed model. Depending on the model, the residual population is the number of people with T1D who live beyond a maximum travel time threshold from the nearest large or smaller healthcare facility providing the services. This means that the T1D population living within the catchment areas of either model are not considered to lose working days. The equivalent equation for calculating the costs in the decentralised scenario (M2), where most visits are made to smaller hospitals, can be found in the Supplementary information.

3. Results

A very different picture of the travel times required for the population to reach each type of service is found in the three countries (Fig. 1). In Ghana, 17 large secondary and tertiary level (regional and teaching) hospitals provided specialised services, and 137 smaller primary level (district) hospitals

provided general services. For Peru, two very large tertiary-level hospitals provided specialised services, and 34 smaller tertiary-level hospitals offered general services. In Nepal, 35 large tertiary-level hospitals (federal and private teaching hospitals) provided specialised services, and 29 secondary-level (provincial) hospitals provided general services. Unlike the other countries, in Nepal, the wide distribution of large tertiary hospitals across the country and their relative affordability facilitates the accessibility of the population to this type of hospitals for specialized services. In contrast specialised services in Peru were highly centralised and located exclusively in the capital, with estimated travel times of more than 24 hours (Fig. 1C) This is reflected in the much higher weighted average travel time per person (6.47 hours) in Peru compared to the other two countries (Table 1). In Ghana comprehensive population coverage of more than 82% for specialised services at the two-hour threshold, and more than 92% for general services at the one-hour threshold (Fig. 2). In Nepal there are similar weighted average travel times for both types of services (Table 1) and in the population coverage (Fig. 2), both of which exceed 70% at the two-hour threshold, but that is quite low for the one-hour threshold (44% for general and 46.7% for specialised services). Whereas in Peru only about 35% of the population has access to specialised services within two hours (Fig. 2). For general services, population coverage is just over 50% at one hour of travel time, as hospitals serve the main urban areas (Fig. 1D). More detailed country figures with administrative divisions are provided in the Supplementary information.

Table 1
Weighted Average Travel Time (WATT) in hours per person for each trip, according to the country and model.

Country	Model	Travel time (h)	Prevalence 2024	WATT h/person (min)
Ghana	Centralised (M1)	12,809	11,410	1.12 (67)
Ghana	Decentralised (M2)	4,657	11,410	0.41 (24)
Peru	Centralised (M1)	39,929	6,170	6.47 (388)
Peru	Decentralised (M2)	12,107	6,170	1.96 (117)
Nepal	Centralised (M1)	25,775	17,130	1.50 (90)
Nepal	Decentralised (M2)	24,565	17,130	1.43 (86)

3.1. Cost analysis

After estimating the median costs for medical appointments and tests, consumables, and travel, we used these figures to calculate the final costs (Table 2). For 2024, the estimated median annual cost of T1D management in a centralised system in Ghana was more than USD 8.53 million, or about USD 748 per person. For Peru, it was about USD 7.89 million, or about USD 1280 per person, and for Nepal, a total of USD 8.55 million, equivalent to USD 499 per person. These costs are largely driven by fixed costs (consumables and medical appointments), which represent 95.5%, 74.9%, and 86.7% of the total costs in

the centralised model (M1) for Ghana, Peru, and Nepal, respectively. Similarly, they account for 98.1%, 86.7%, and 84.6% of the total costs for the decentralised model (M2). For both Ghana and Peru, the travel (variable) costs are higher in the centralised model (2.4 times higher for Ghana and 2.2 times higher for Peru). Figure 3 presents a comparison of the costs per model, with and without fixed costs, for each country.

Table 2

Estimated medical, consumable, travel, and total costs per country in USD.

Country	Median cost (USD)		
	Ghana	**Peru**	**Nepal**
Medical appointment			
Specialist (once per year)	8.37	4.17	4.65
General practitioner or prof. nurse	8.14	2.94	0.26
Medical exams (once per year)	31.27	1.19	25.99
Consumables			
Glucometer (1 year)	13.03	37.68	15.00
Insulin (1 month)	9.50	15.00	9.00
Glucose strips (1 month)	27.86	50.86	20.58
Lancets (1 month)	4.13	13.36	1.09
Syringe (1 month)	7.43	3.23	3.28
Travelling			
Loss of work (per day)	1.66	10.60	4.85
Motorized travel (per hour), med. (IQR)	1.17 (0.72, 2.12)	1.75 (1.14, 3.24)	1.52 (0.92, 3.14)
Total annual costs (models)			
Fixed costs per person (total)	729.2 (8,320,742.5)	1060.8 (6,545,013)	456.5 (7,819,845.4)
Travelling costs (M1) per person (total)	34.14 (389,560.5)	354.71 (2,188,571.7)	70.29 (1,204,062)
Travelling costs (M2) per person (total)	14.08 (160,606.5)	163.24 (1,007,199.6)	83.28 (1,426,554)
Centralised service (M1) for the prevalence, med. (IQR)	8,710,303 (8,572,288–9,001,669)	8,733,584 (8,149,157 – 10,161,120)	9,023,907 (8,653,899–10,022,929)
Decentralised service (M2) for the prevalence, med. (IQR)	8,481,349 (8,424,664–8,601,017)	7,552,212 (7,341,219–8,067,589)	9,246,399 (8,892,219 – 10,202,684)

The average cost of a round trip to the nearest large hospital, for specialised services, is estimated to be 0.79 of a minimum daily wage in Ghana, 1.29 in Peru, and 0.56 in Nepal, while the corresponding average

costs to reach the nearest general hospitals are 0.33 in Ghana, 0.59 in Peru, and 0.66 in Nepal. As Fig. 3 shows, absolute travel costs (including lost labour) are lowest in Ghana, partly due to the lower minimum wage, but also because of very cheap public transport. In contrast, absolute travel costs are highest in Peru, due to the much higher daily minimum wage and the particularly long distances to be travelled, especially in the centralised model.

Regarding fixed costs, the same comparison shows that these costs are proportionally much higher in Ghana than in the other two countries. For Ghanaians, the fixed costs correspond to about 16.9 minimum daily wages, whereas in Peru they are only 3.8 and in Nepal 3.6.

4. Discussion

To our knowledge, this is the first time, geospatial analyses have been used to assess the geographical accessibility and cost of delivering T1D care in LMICs. The aim was to compare two service delivery strategies for people with T1D in terms of geographical accessibility and related costs. To analyse geographical accessibility, we estimated the travel time required for the population to reach the nearest health facility. Using geospatial analysis, we estimated the costs associated with two overarching models of T1D healthcare service provision, dividing them into fixed and travel-related costs.

The distribution of large and smaller hospitals in the three countries studied revealed significant differences in accessibility to healthcare services. Ghana and Peru had centralised services, with Peru in particular having limited geographical accessibility to specialised services. In contrast, Nepal had more decentralised services, resulting in better geographical accessibility to all services. In all three countries, fixed costs accounted for the largest share of total costs. The remaining costs, mainly related to travel and productivity losses among the affected population, were strongly influenced by geographical factors such as the distribution of health facilities, country size, transport infrastructure, and landscape characteristics. This is reflected in our results: Ghana, a relatively flat, medium-sized country with many affordable transport options, showed only a small difference (2.6%) between the fraction of total costs represented by travel costs in the centralised and decentralised models. In contrast, Peru, a much larger country with highly complex geography, exhibited a much greater difference in the percentage share of travel costs between the two models, at 11.8%. Nepal's results were very different, as it is a small country with challenging geography and deteriorated transport infrastructure. However, it compensates for its limited mobility with a well-distributed network of public and private, relatively affordable health facilities for both general and specialised services, resulting in a difference between the proportion of total costs represented by travel costs between models of only 2.1%. These results highlight not only the importance of geographical factors and how they can affect accessibility and travel-related costs when planning service delivery strategies, but also that there is no single predominant factor determining the final results. Beyond average travel times and costs, these patterns also have important equity implications: populations in remote or poorly connected areas bear disproportionately higher travel and productivity losses, as well as limited access to healthcare, which can lead to poorer health outcomes.

Service delivery planning and resulting geographical access to health services can exacerbate existing socioeconomic and geographic inequities in access to T1D care[47].

Previous studies using geographical access have mainly been carried out in high income countries (HIC) Australia, Canada, Denmark, or Finland[17,36,48–50]. Joshi et al.[50] exemplified how in Western Australia an efficient decentralisation approach involving only one specialist visit and multiple local visits via outreach teams, resulted in similarly good glycaemic outcomes for rural residents than for metropolitan inhabitants living closer to large hospitals[50]. Similarly, an example from Canada showed higher care satisfaction and lower HbA1c for children treated locally and not requiring long drives for their check-ups[36]. Finally, in Finland a comparative study of centralised versus decentralised care, also reported no differences in glycaemic outcomes, and instead higher satisfaction for being treated by local general practitioners, and less costs in the decentralised model[49]. These examples from HICs lean towards the idea of decentralisation when travel distances become more important in time and cost, which in LMICs can become a burden[12]. Several countries in LMIC have decentralised models (e.g., Cambodia, Malaysia, Laos, or Bangladesh) or are moving towards decentralisation, aiming to reduce that burden and optimize resources and population coverage[12]. For example, Uganda has implemented T1D care at the primary level, following the chronic care model, in which dedicated personnel at the primary level are supervised by specialists[51]. A recent scoping review evaluating decentralised chronic care in LMICs found that provision at primary and first-referral levels was inconsistent and unreliable when available, and since centralised services alone are unlikely to provide equitable care to rural populations, decentralised approaches with targeted intermediate standards, such as the PEN-Plus model, are needed[52]. Other countries are implementing the PEN-Plus model[53], which focuses on reducing geographical barriers by decentralising specialised care for severe NCDs, including T1D.

4.1. Limitations

This study presented some limitations. Firstly, in LMICs, information on health service provision can be limited. In some cases, databases and surveys describe the most common services and resources, but they rarely cover highly specialised service topics, such as the treatment of T1D. Our selection of health facilities for this modelling was based on the best available online resources and local expert advice. However, these resources may not be fully complete or precise. Secondly, our motorized travel scenarios are based on realistic but general assumptions applied at the national level. This may not capture some sub-national travel specificities, such as particular modes of transport and travel speeds. This could result in either shorter or longer travel times to services, which would affect our cost estimates. Thirdly, information on the costs of fixed items was scarce, which precluded the use of cost ranges. In addition, based on available sources, we could not assume that people with T1D in the centralised model would have all their appointments, including check-ups, with a specialist, which would have increased the costs of that model significantly. Fourthly, our accessibility analyses were based on travel speed estimations that generally represent mobility under normal conditions, usually during the dry season when all roads and paths are passable. Mobility during the rainy season may not only be reduced, but in many cases

severely hindered. This will require a detailed, dedicated analysis including new barriers to movement, reduced travel speeds, and possible absenteeism. Fifth, Travel time estimation in AccessMod depends on both objective geospatial layers and subjective travel speed scenarios. For the former, users should obtain broadly similar results, even if data sources differ. For the latter, however, substantially different estimates may be produced by different authors. Differences between AccessMod results and self-reported travel times have been noted previously[54]. However, both self-reported and AccessMod travel times contain subjective components, which means they both remain estimates. Finally, it is important to emphasise that LLM outputs are non-deterministic, as the sources for various costs, such as travel guides, pharmacies, and transport companies' websites, can change regularly and values can be updated.

5. Conclusions

Planning for T1D services highlights the unique challenge of optimising care delivery for a low-prevalence condition, in contrast with other chronic conditions such as hypertension or type 2 diabetes, for which global strategies focusing on strengthening primary care already exist[55]. This challenge is greater in resource-constrained settings, where careful planning to maximize the use of available resources is crucial. In this context, geospatial analysis is an essential tool for planning service delivery strategies. Such modelling of population travel times to treatment facilities can also serve as a blueprint methodology to provide relevant information for health system planning and redesign. Explicitly incorporating equity into service delivery planning is crucial, as decisions about where to locate services and how to organise referral pathways can either mitigate or reinforce existing disparities in access to healthcare and financial burden among different population groups. The results indicate that decentralisation of specialised health services in any form tends to bring these services closer to the population and reduce costs. Considering the large possible number of factors that each country might present for this type of analysis, we aim to provide a template for exploring dedicated analyses for each unique scenario.

Declarations

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Author Contribution

COP contributed to writing the original draft, investigation, methodology development, formal analysis, data curation, conceptualisation, and visualisation. JHZT contributed to writing, review and editing, methodology development, conceptualisation, and investigation. BDN contributed to writing, review and editing, investigation, and validation. BS contributed to writing, review and editing, investigation, and validation. DB contributed to writing, review and editing, conceptualisation, investigation, supervision, resources, funding acquisition, methodology, and project administration. NR contributed to writing, review and editing, supervision, resources, and methodology development. All co-authors have approved the submitted version.

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Data Availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Figures

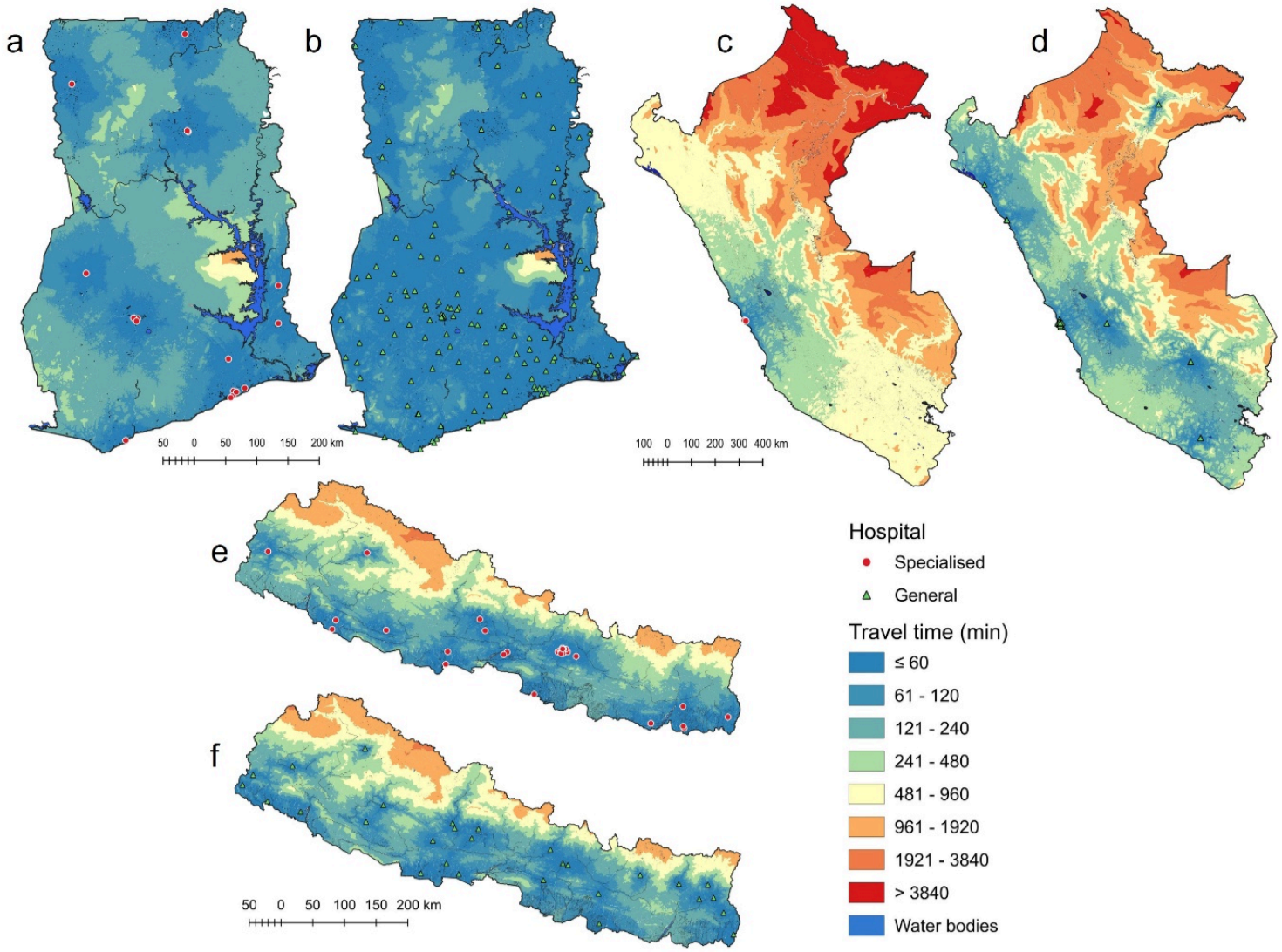


Figure 1

Travel time and health facility distribution for all models and countries. *Ghana centralised (a) and decentralised (b), Peru centralised (c) and decentralised (d), and Nepal centralised (e) and decentralised (f)*

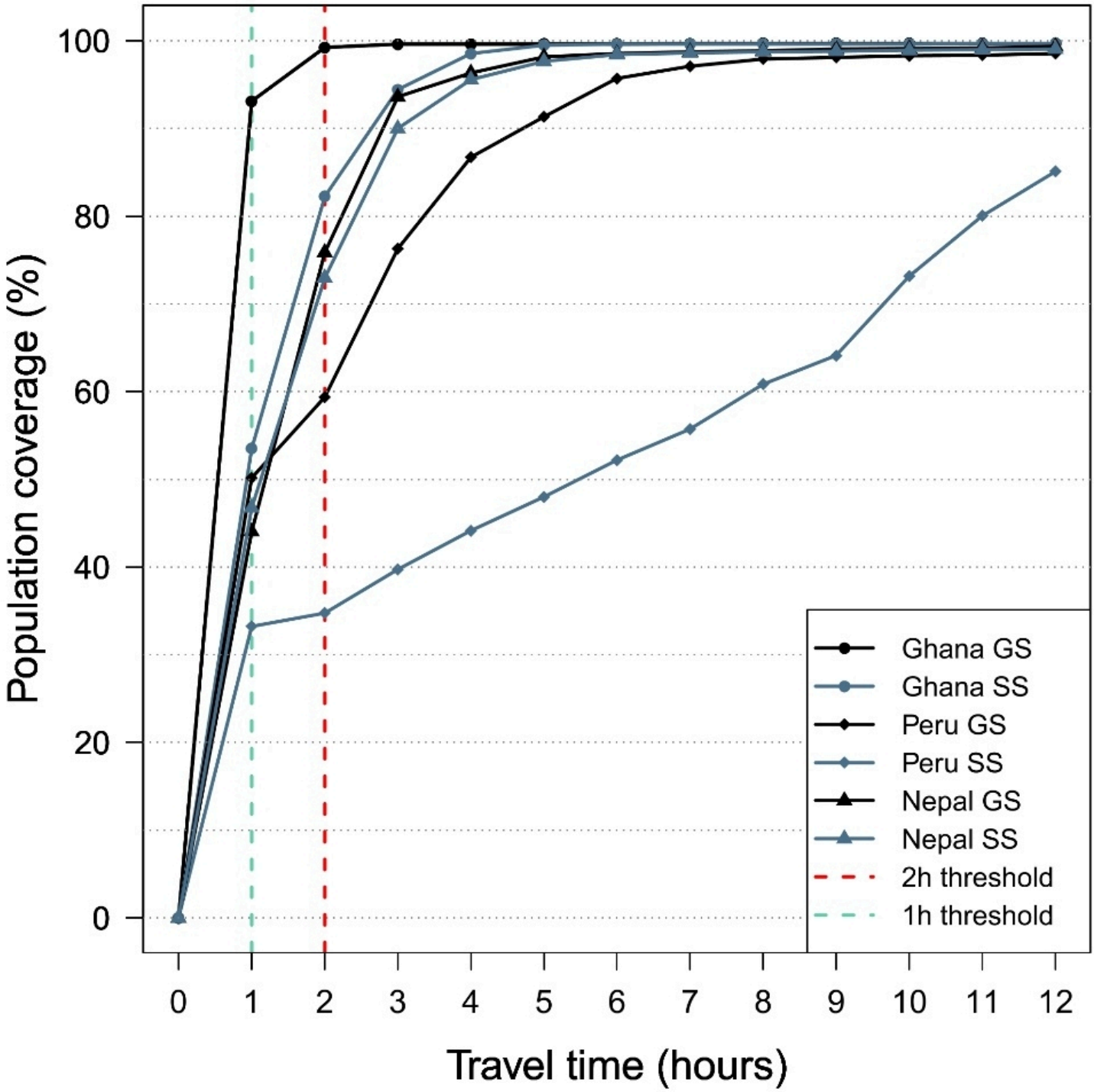


Figure 2

Cumulative population coverage for the three countries and two models. *GS represents General Services and SS Specialised Services.*

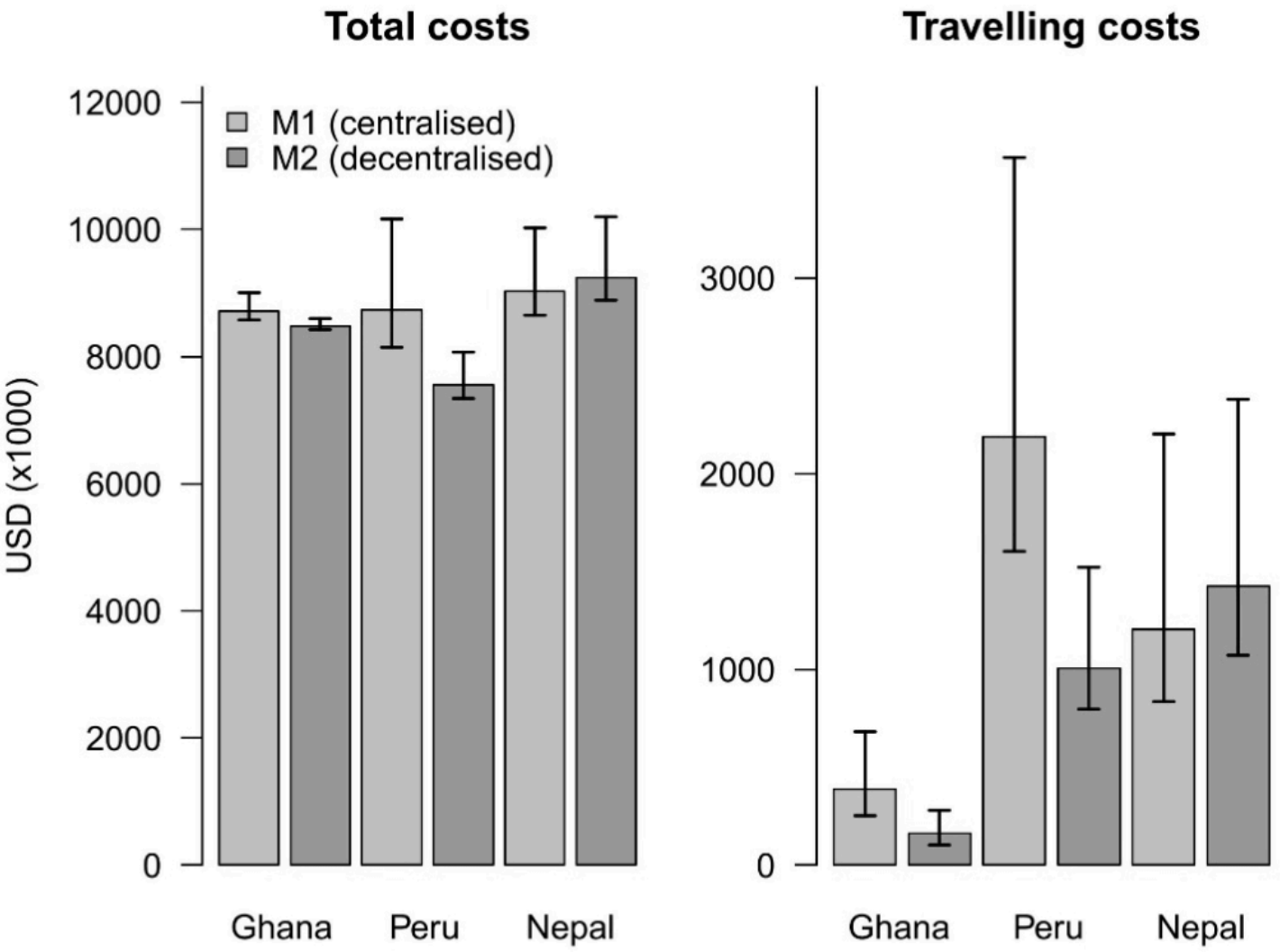


Figure 3

Cost comparison with total costs and travelling costs only (without fixed costs)*. The bars represent the median and the lines the IQR.*

Supplementary Files

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