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Technology in education

SCHOOL MAPPING AND DECISION-MAKING

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ABSTRACT

Reliable and timely data is essential for decision-makers at all administrative levels to ensure inclusive, equitable, and quality education for all. Geospatial data has the potential to provide valuable insights across a range of areas of interest to the education sector, from identifying potential threats to schools and the education community, such as through data on natural disaster patterns, to supporting equitable allocation of resources based on data showing the remoteness of schools. However, the use of Geographic Information Systems (GIS) is not widespread in the education sector. In this paper, we shed light on the experiences of five country governments, one regional agency, one international initiative, one implementing partner and one private entity, all using GIS for education decision-making in Latin America, the Caribbean, and sub-Saharan Africa.

This paper presents the findings from primary data collection and analysis of interviews with representatives from these organisations from August – December 2022. Across these countries, we identified two central applications of school geospatial data, which included education planning - which school mapping is a part of - and cross-sector coordination. Among the main challenges to effectively using school geospatial data to make decisions, we found significant issues with capacity building, funding, bridging the data, and policymaking. On the other hand, when school mapping was used effectively, it helped increase transparency and equity, intersectoral collaboration, cost-effectiveness, and accuracy and reliability. After comparing the seven cases, we concluded that two key enablers need to be in place to promote the impact of geospatial data on educational decision-making: 'usability' and 'availability and openness'.

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Acronyms

CDEMA	Caribbean Disaster Emergency Management Agency
GIS	Geographic Information System(s)
IGED	Instancias de Gestión Educativa Descentralizada (Decentralised Educational Management Agency)
KEMRI	Kenya Medical Research Institute
KESSP	Kenya Education Sector Support Programme
MBSSE	Ministry of Basic and Senior Secondary Education
RIE	Registro de Instituciones Educativas (Registry of Educational Institutions)
UGELES	Unidad de Gestión Educativa Local (Local Educational Management Units)
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
USAID	United States Agency For International Development

1. Introduction

Reliable and timely data is essential for decision-makers at all administrative levels to ensure inclusive, equitable, and quality education for all. In particular, geospatial data for educational planning can help improve access, service delivery, and more equitable resource allocation, as it reveals relationships that have been proven to impact education outcomes. For example, we know that proximity to school has been identified as a key factor for low enrolment rates (⇡Rodriguez-Segura & Kim, 2021) and higher teacher absenteeism (⇡Lee et al., 2015; ⇡Nugroho & Karamperidou, 2021). Additionally, inequitable allocation of teachers and resources to schools leads to shortages in the most-needed areas, such as hard-to-reach schools (⇡Avvisati, 2018; ⇡Ingvarson et al., 2013). Teacher attendance and retention in hard-to-reach schools are also challenging, given teachers' preference for proximity to financial institutions, healthcare, and other basic facilities (⇡Lee et al., 2015).

We know from other sectors' experience that geospatial data can inform systems planning, supporting stakeholders at all levels to make more informed and equitable decisions about resource and service allocation. Nevertheless, in the education sector, the use of geospatial data has remained relatively limited despite an increased emphasis on evidence-based decision-making. However, developments in technology are increasingly making data collection and analysis more accessible and sophisticated; therefore, it is important to understand better how this data is being collected and used and the impact on education outcomes.

1.1 Geographic Information System(s) for education

Geospatial data for education is more complex than just information about a school's location. Decisions on where to build schools, place teachers, and allocate resources require granular geospatial data in conjunction with various school data and other attributes. This might include data such as actual distances travelled to schools, school conditions (like access to water and electricity), and school proximity to basic facilities (like health clinics). This merging of geospatial and other attribute data is usually undertaken with Geographic Information Systems (GIS).

In this paper, we define **Geographic Information Systems** (GIS) as “a system that generates, maintains, analyses, and maps all types of data” (⇡ESRI, no date). A GIS connects data to a map and combines location data with descriptive data and about other attributes, such as student enrolment, number of teachers, or school facilities. **School mapping** is a collection of methods and processes used to assess national and local educational demand and service delivery, alongside other important information on education outcomes. A **school map** shows schools’ geographic positions and provides information about their attributes. **School maps** are static, while school mapping provides a dynamic vision of what the education service looks like, displaying data related to classrooms, enrolment, gender, teachers and facilities, among other things, in order to facilitate the design and implementation of education policy and planning by using geographical units of analysis (⇡UNESCO IIEP, 1983; ⇡UNESCO IIEP, 1996).

Most evidence on school maps and school mapping in education suggests that maps are especially critical for infrastructure planning and resource allocation to improve equity and efficiency in service delivery. For example, Sierra Leone has used geospatial data and analysis to support its School Infrastructure and Catchment Area Planning Policy (⇡Sierra Leone Ministry of Basic and Senior Secondary Education, 2021). Prioritisation tools have been developed that identify the best place to build a school, to facilitate the implementation of this policy based not just on population but also on the poverty level and on how far away populations are from the nearest schools (⇡Momoh & Atherton, 2022). As an example of GIS to support resource allocation, USAID Malawi has used GIS to track implementation of a coaching intervention to ensure adequate and equitable coverage.

While there is some research on the different applications of GIS in education, there is limited evidence on the challenges, impact, or enablers for its effective use. This paper aims to shed light on these issues and provide suggestions for how governments and other actors can better leverage GIS and school mapping for improved education for everyone.

1.2 Structure of this paper

This paper is focused on Africa, Latin America, and the Caribbean. It begins by detailing the research methodology (Section 2), then discusses the findings in terms of collection and analysis of geospatial school data (Section 3), applications of school mapping (Section 4), the impact of school mapping (Section 5), and enablers for effective use of school mapping for decision-making (Section 6). It concludes with a summary of the key insights and a set of recommendations based on the findings (Section 7).

2. Methodology

This study used qualitative methods with primary data collected through semi-structured online interviews with nine stakeholders from a mix of governments, donors and implementing partners, non-governmental organisations and private entities using school location data for national, regional, and global decision-making. These included:

- Argentina: Mapa Educativo Nacional, Dirección de Información Educativa / National Educational Map, Directorate of Educational Information
- Caribbean Disaster and Emergency Management Agency (CDEMA): GIS Department and Safe Schools Department
- Development Seed: an engineering and product company that is accelerating the application of earth data, including applications to help countries identify unmapped schools
- Giga: Global UNICEF-ITU initiative to connect every school to the internet and every young person to information, opportunity and choice
- Jamaica: Educational Planning Unit, Ministry of Education and Youth
- Kenya: Kenya Medical Research Institute (KEMRI)
- Malawi: USAID Malawi
- Peru: Unidad de Estadística, Ministerio de Educación / Statistics Unit, Ministry of Education

- Sierra Leone: Directorate of Policy and Planning, Ministry of Basic and Senior Secondary Education

Countries and organisations were selected based on existing relationships and collaborations with policymakers and technical experts and through connections with the GIS for Education Working Group.[1] In selecting countries, we tried to provide a diverse representation of geographic and economic development contexts.

The interviews with stakeholders were recorded, transcribed, and coded. We followed an inductive coding process using the qualitative analysis software Atlas.ti. By the end of the analysis phase, we had developed over 30 codes corresponding to four main thematic areas:

1. Data collection and analysis of geospatial school data (process, methods, formats, and challenges)
2. Applications of school mapping (including challenges)
3. Users of GIS data
4. Impact of GIS data on education sector decision-making

To ensure rigour, we assessed the reliability of our coding with an external rater who coded 10% of the interviews. We found agreement of almost 100%, which suggests a reliable coding process. Similarly, to confirm that the report accurately reflects what the interviewees said, we shared a draft with them for revision. Finally, we also consulted other resources like reports and databases to understand the context, depth, and complexity of the work of the organisations listed above.

2.1 Ethics

We explained to participants how their data would be used through email, an official letter, and during the interview. We asked participants to sign a consent form detailing the management of their data and the freedom to withdraw consent at any time, even

[1] https://educationcommission.org/gis-for-education-working-group/ Retrieved 21 November 2022

after the interview had been held. Only the research team accessed the raw data, which is retained for six months beyond research completion only.

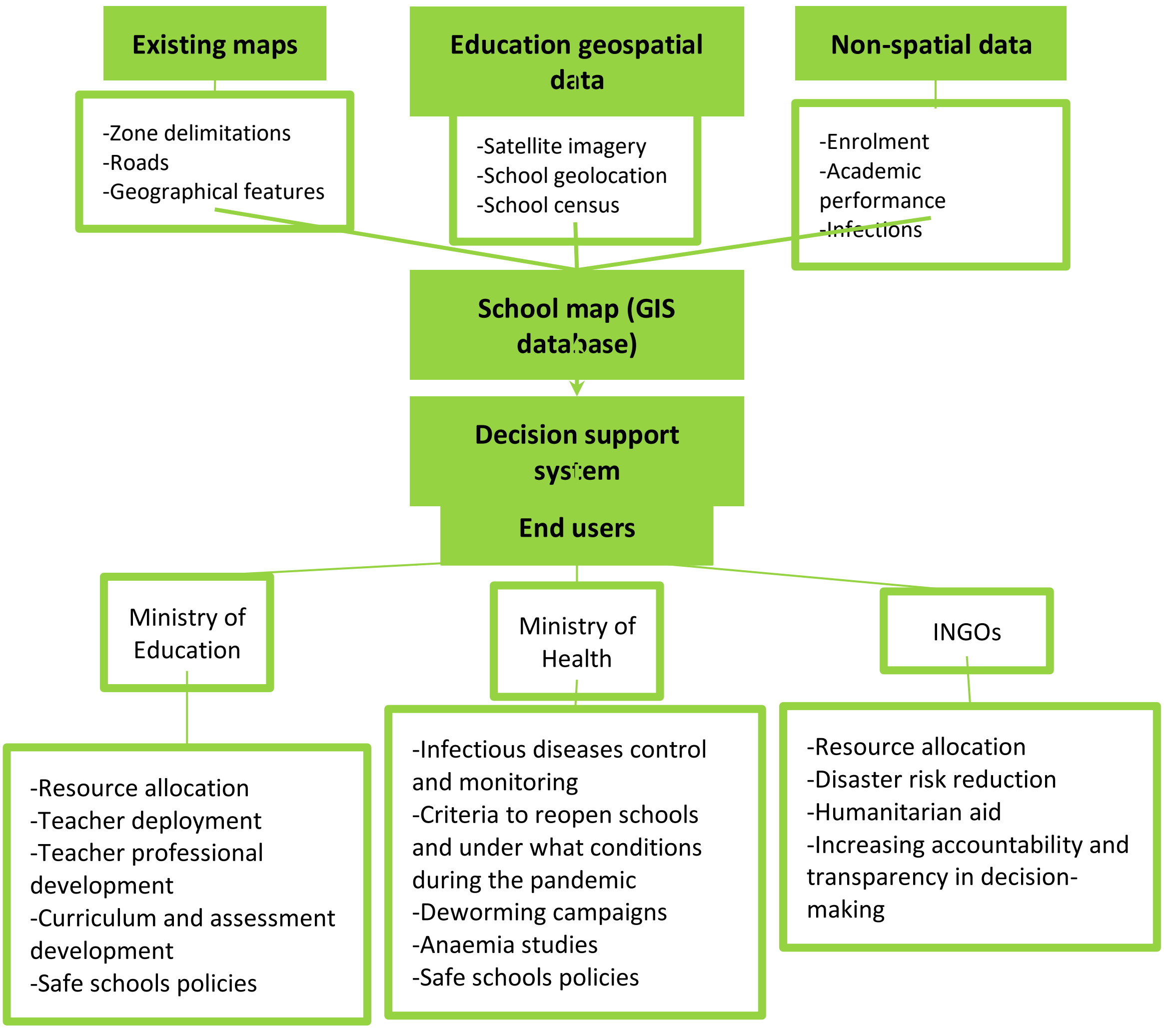
3. Collection and analysis of school location data

The introduction of georeferencing schools and creating a school map for education decision-making has varied across countries. From those we interviewed, a couple started as early as the 1980s and 1990s (Peru and Jamaica), and others in the early 2000s (Argentina). However, for some, school maps were introduced only as recently as five years ago (Sierra Leone).

Recent technological advancements in the GIS field have made geospatial tools available to education ministries and others working in education. With the cost-reduction and performance improvements of computing and the availability of low-cost location-enabled mobile phones, the costs of this exercise have been significantly reduced. The school mapping process evolved from desktop to server and currently uses a range of tools, including desktop, mobile, server, and cloud (⇡Rees, 2018). Today, more technologically advanced techniques, such as machine learning and artificial intelligence (AI), can be used to identify where schools are located.

Figure 1 illustrates how different inputs of data are integrated, compared, and layered to obtain a more holistic and comprehensive understanding of the education sector. This data is then used to support decision-making and finally reach multiple users.

Figure 1: Data sources and users of GIS in education



This section will explain the school mapping processes and explore the challenges in location data collection and analysis for the countries and organisations included in this study.

3.1 Organisational structure of the school mapping departments

The worldwide trend is to decentralise the educational system and transfer responsibilities to the local level. However, **in most countries, the responsibility for developing and managing school mapping is centralised,** primarily due to a lack of human resources, institutional capacity, and funding to support this work locally. Although in some countries functions like data collection and validation have successfully been transferred to local offices, school mapping is still primarily employed at the central level for decision-making. In fact, the predicted benefits of school mapping and decentralisation are significantly diminished when regional plans cannot be developed and implemented independently (⇡Sylla & Tournier, 2013). A few advantages of maintaining the development of the school mapping process at the central level include ensuring the accuracy and comparability of the data, avoiding the risk of not having technical capacity in all regions or districts, and reducing costs, such as software licences. This does not mean that local governments do not use it or participate in the process; rather, it implies that, depending on their central and local capacities, each country must find an approach that makes school mapping meaningful. For instance, in the appendix 5, organigrams from Sierra Leone and Peru show the centralisation of school map for decision-making.

In the majority of the countries we focused on for this study, the creation of a school map falls within the remit of the central government, but with the assistance of regional offices, e.g. at the district level. The central offices are in charge of gathering information, ensuring the accuracy of the data, and closely coordinating with offices of statistics in order to add data from other sectors to the maps for analysis, such as climate, population, and road network data.

The agency or department responsible for school mapping within the central government varies. For instance, in Sierra Leone, the Ministry of Basic and Senior Secondary Education (MBSSE) was tasked with gathering statistical data, including school location, through a memorandum of understanding under the National Strategic Development Plan; the director of planning and policy at the MBSSE oversees this work. This organisational structure is also present in Jamaica, where the Education Planning Unit handles school location planning within the Ministry of Education and Youth.

In Peru, the statistics office of the Ministry of Education is responsible for school mapping; it has six areas of coordination, one of which is territorial analysis, for which a school map is generated and examined, and technical assistance is given to other areas requiring georeferenced educational data. Local offices known as the Decentralised Educational Management Agencies (Instancias de Gestión Educativa Descentralizada or its acronym, IGED) are in charge of the data collection at the Ministry level.

Mapa Educativo Nacional (the National Educational Map Office) in Argentina is currently located within the Information Technology (IT) department in the Ministry of Education. However, it was previously located within the planning department. Regardless of where the office sits within the ministry, its primary goals are geospatial data collection and analysis and assisting with the various demands for data from the other departments within the ministry.

These few examples highlight how difficult it is to pinpoint a single agency responsible for school mapping because of different pre-existing governmental structures in different countries. The only feature these structures share is that, despite decentralisation efforts, the mandate for school mapping is typically still held by the education ministry at a central level.

3.2 Collection approaches and tools

School map technology has advanced to the point where AI models are now an option. This analyses high-resolution satellite data and employs a trained algorithm, also known as pattern detection, to identify structures that are likely to be schools, flagging them for human assessment. The data collection process differs from country to country, just like the organisational structure of each office in charge of the school mapping. This variation is primarily due to the tools and technical capabilities of each country. The key aim of the offices is to collect the location and characteristics of schools and surrounding communities; once compiled, this data is combined with geospatial data available. For instance, performance data, socioeconomic variables, health and infection rates, and environmental data –among others– can be integrated with geographic information to provide a comprehensive view of the challenges that might impact education in that particular school. **There is a close relationship between school censuses as a source of primary information to enrich the school maps and the process of creating school maps,** as is the case in Sierra Leone and Argentina. However, other countries, such as Peru and Jamaica, employ a separate registration process for educational establishments that is not linked to the school census. While the school census is typically updated only annually, school facility records tend to be updated more frequently.

Today, **the most popular method of collecting location data is through mobile devices like tablets or smartphones that can record geographic coordinates in real time**; the data is then processed later using GIS software. The collection of this data takes place at various times. In the majority of cases, it is gathered during the school census, which usually occurs annually. In some countries, like Jamaica, a team is sent to gather the data and keep the school map up-to-date when a new school is added to the existing roster of schools.

> **That is ongoing because each time we have one additional school added to the public school listing, it is normal to collect the coordinates in order to map that specific institution for the existing public schools' dataset. Essentially, we rely on the annual school census data to populate the school information on the GIS mapping. — Jamaica**

In Argentina, the school census is used to create the school map; however, instead of collecting the geospatial coordinates to place the schools on the map, the layer of schools is created using the addresses and/or spatial references and GIS software. The National Educational Map Office completes this work, but because it requires a more manual process, the map may become out-of-date if human resources are insufficient.

Peru uses a hybrid system. The process involves identifying schools regularly, using a school list, which is soon to become the Registry of Educational Institutions (Registro de Instituciones Educativas (RIE)); this happens at a local level. With this information, the central office can determine where each school is located and geolocate it on a map. If a school cannot be located, the Local Educational Management Units (Unidad de Gestión Educativa Local, UGELES) are asked to review the map area or physically go to a school in order to locate it; this process is repeated frequently in order to prevent a backlog. In 2022, 45% of the school census and the coordinates were collected through a mobile application for the first time as a pilot, making it easier to locate schools in remote areas with poor access. This process will also contribute to validating the geolocations of the school list.

In Malawi, an out-of-date map was in use before a large data collection initiative in 2016 in which USAID collaborated with district offices to identify the primary and secondary schools, updating and digitising the zone delimitations, and measuring distances, particularly to secondary schools to ensure girls' access. . A field team was sent to the missing schools to collect coordinates and confirm the geolocation to later update the map. This information, as well as the procedure to collect and analyse it, is now used by the Ministry of Education and other government agencies to continue planning efforts in the country.

The Kenya School Mapping project was developed as one of the tasks of the Kenya Education Sector Support Programme (KESSP) 2005–2010. Using school list archives maintained by various organisations and authorities, KESSP augments them with data auxiliary sources. For example, geospatial factors that affect travel to school, environmental factors associated with disease of interest (health outcome), population distribution of school-going children among others. These datasets are then carefully merged, accounting for errors and duplicates. The final master list is geocoded using open sources. These datasets are processed mainly by GIS assistant research officers. For the analysis, remote sensing products are used for auxiliary data sources and environmental variables. The initiative positioned all educational institutions using GNSS. During the data collection process, KESSP also collected information regarding the physical state of facilities and the number of students and teachers (⭱Ministry of Education, Science and Technology, 2005; ⭱Mulaku & Nyadimo, 2011).

Lastly, the Caribbean Disaster Emergency Management Agency (CDEMA)[2] has school data from 6 out of 19 participating states (Grenada, St. Lucia, St. Vincent, Dominica, Trinidad and Tobago, and Belize). Data collection was undertaken in three main ways: the first involved using aerial photography on a regular basis, whereby a combination of Lidar and aerial photography was used for each country; the second used satellite imagery for data collection; and the third used schools' geographic coordinates. We do not have more detailed information regarding how and which countries are using each methodology.

3.3 Challenges in the data collection and analysis

The various country offices and organisations that produce and use school maps have identified a number of challenges related to the data collection and analysis process,

[2] The Caribbean Disaster Emergency Management Agency (CDEMA) is a regional intergovernmental agency for disaster management in the Caribbean Community.

including the technical capacity of the team and users, accessibility and software constraints, funding and information privacy. Each of these issues is discussed below.

One of the biggest challenges for governments is technical capacity. Two viewpoints are presented here: that of the map users, such as governments or non-governmental organisations, and that of the map developers. First, to produce the data, significant human resources are needed to collect, process, analyse, and prepare the information in a user-friendly format. Users need specific technical skills to use the geospatial information produced, frequently requiring specialised software like ArcGIS and QGIS, which is an open-source software.

> **(…) I think where it sits now and how it's stored, it's too technical for those different levels of decision-makers and stakeholders to use. — CDEMA**

The teams in charge of school mapping have developed various ways of sharing information with other stakeholders, such as via dashboards, Google Earth data, and interactive and static maps, among others (see Appendix 1).

However, when a user needs specific analysis and requires different layers of data, they will need to use specialised software like ArcGIS, which is expensive and thus often limited to a certain number of licences or users. However, even free open-source software, like QGIS, still requires specialist skills. Therefore, when other departments or stakeholders require a specific analysis, they usually request technical support from the department in charge of the school mapping, which has the technology and knowledge to perform the analysis successfully.

> **One of the limitations, though, is that the software that we use is expensive and it's limited to a certain number of users. — Jamaica**

Financial support is a significant problem most of the countries face, much like the lack of technical capacity. Even though technological advancement has decreased costs, **using GIS for planning education is still expensive — an outlay that many low- and lower-middle-income countries cannot finance without donor assistance.** For instance, Argentina has not hired the necessary personnel in the last few years because it does not have the economic resources to do so. As a result, it has been impossible to maintain the annual updating of the geographic reference system, and only occasional updates are made in response to specific requests for management.

> **Any agency with a spatial data infrastructure needs a lot of people to work on it. It can't be done with just a few people. However, when budgets are cut, as they are in all of our countries, this can be a problem. — Argentina**

Interviewees identified **international organisations** (such as UNICEF or the UNESCO Institute of Statistics), **implementing partners** (such as USAID), the **private sector** (such as Development Seed), and **ministries of education** as the primary users of school maps. However, since the data is typically not accessible to the general public and must be requested specifically, knowledge of the available data and the capacity to coordinate between different organisations and stakeholders can be constrained. For example, CDEMA mentioned that they must connect with the ministry in each of the 19 countries they work with to understand what datasets are available.

Another challenge identified was the duplication of efforts and weak inter-agency communication and collaboration. Countries often collect school map data already collected by other organisations using different methods, like satellite imagery. Cross-checking the information collected by all stakeholders would promote more efficient collection methods, allow for more reliable data, better inform decision-makers, and help save resources invested in collection that could be allocated to analysis or implementation.

Privacy and ethical issues are discussed in the literature (⇡Berman et al., 2021) but were not mentioned as a challenge during the interviews. Although school location data is often already available as open source, when school geodata is integrated with other databases, it may be possible to identify certain groups of people or individuals, putting them at risk if identifiable personal details are disclosed alongside their geospatial locations. Examples include teachers on payroll and children with disabilities or pregnant girls. To ensure a certain level of anonymisation, owners of the school maps must be cautious about who has access to them and about sharing and interpreting the data. In particular, care should be taken over personally identifiable data such as names, IDs (particularly relating to payroll), and contact details — these should be removed from public databases as a default and only included for particular need cases. Some databases, like Demographic and Health Surveys (DHS), randomly displace the GPS latitude/longitude positions for each survey in order to maintain respondent confidentiality.

4. Applications of school mapping

The country governments and representatives from other organisations and entities we interviewed reported using school map data for diverse purposes. We identified two overarching application categories with a range of uses under each. The first is **education planning**, particularly for infrastructure and resource allocation, and the second is **cross-sector coordination**, especially with health and emergency services.

4.1 Education planning

The two most cited applications of school map data under education planning were for identifying and prioritising **infrastructure** needs and **resource allocation**.

Infrastructure

All the countries and organisations interviewed reported using school mapping for infrastructure planning. One of the most common uses is determining where to build **new schools**.

Malawi has used GIS data to determine where to build new secondary schools to address a specific problem with low transition rates from primary to secondary. In addition to looking at a set of selection criteria for new schools, USAID uses GIS data to understand how primary schools are clustered around existing secondary schools to identify areas in greatest need. Similarly, in Argentina, a method based on combining educational indicators with GIS data has been created to identify regions with a high need for children to be enrolled in pre-primary school to maximise the effectiveness of addressing unmet demand and establishing new schools (⇡Sendón, 2022).

Sierra Leone has developed a cutting-edge optimisation tool that can tell stakeholders the best place to build a new school based on population, poverty level, and how far away students are from the nearest schools. New features are also being built into the tool to help determine climate-smart locations based on flood data.

In Sierra Leone, geospatial data is also being used to prioritise which schools to **renovate and expand** with extra classrooms and WASH facilities based on different sets of criteria (such as pupil–teacher ratios, pupil–latrine ratios and other relevant indicators). The Director of Policy and Planning, explained:

> **It [school mapping] gives a sense of direction as to actually where resources should be placed when it comes to infrastructure development… in terms of the level of schools that you need. [I]t also gives you the condition of the school in terms of actually taking cognisance of the water, sanitation, and hygiene facilities of schools… so these are important things that the school map will show you because it shows you the physical condition of the school. So, as government, [this allows us] to be guided as to what actually will be our focus – Sierra Leone**

School-level data has also been used to **assess risks** and support infrastructure planning in emergencies and natural disasters. CDEMA uses school mapping in the Eastern Caribbean States to help assess the structural integrity of schools in natural disaster risk zones. In Sierra Leone, geospatial data was used to determine network coverage to inform the radio teaching programme for remote learning during Covid-19-related school closures.

School mapping also supports the provision of **amenities**, like internet coverage. The main application of school mapping for the Giga initiative is to identify internet coverage for schools in order to support increased accessibility. In some countries, Giga also collects data on real-time internet speeds at schools to improve connectivity.

> **With this information, we can work with the telecommunication companies, for example, to see how far the cell towers are located from these individual schools and how far these fibre optics nodes are located from the schools, which essentially informs us how much money it will take to connect those schools – Giga**

Resource allocation

Most of the country representatives we interviewed reported using school mapping to inform resource allocation. Jamaican interviewees mentioned the use of school mapping to indicate where **teachers** are most needed and to inform the distribution of resources. Argentina uses the data to inform the distribution of **computers** to rural schools. Malawi has used GIS data to track school monitoring and the implementation of a **coaching** intervention. In Sierra Leone, the school map helps decision-making prioritise which schools should receive financial support to increase the number of students attending financially supported schools.

Countries use the data to zone or group schools by **clusters** for better resource distribution. For example, Kenya and Sierra Leone use geospatial data for catchment area planning, and Peru uses it to consolidate groups of small remote schools into larger areas to help improve management efficiency. In Malawi, isochrone maps showing distances of schools and real travel time (based on physical features) to teacher development centres reveal resource inefficiencies in terms of existing zones.

> **So these are also factors that help administrators to think about to reflect in terms of whether they would want to re-demarcate the zones, how can then they best re-demarcate to navigate through different physical features, but also in terms of management and resource allocation. We may have a zone that has got eight [schools] another one that has got eight [schools], but in terms of size, in terms of travel time, in terms of physical factor, they may be different. So, resources are better located if they refer to this kind of mapping and see how they can best manage based on what is obtaining on each of these zones. — USAID Malawi**

Similarly, in Kenya, more accurate travel times for students walking to schools are computed using geospatial data and help to ensure government travel thresholds are met (⇡Macharia et al., 2022).

4.2 Cross-sector coordination

Most of the countries and initiatives we interviewed reported that the school map data they collect is used by and in conjunction with other sectors, from health to agriculture. The coordination includes other government ministries and agencies, non-governmental organisations (NGOs), and the private sector. **This approach makes sense and is supported by our findings of a strong relationship between schools and the provision of other national services.** Schools were reported as serving as sites for school feeding, emergency shelters, and the provision of health interventions and other social services.

Jamaica, Argentina, and Peru reported that school mapping is used to understand **the proximity of schools to other social services.** In Peru, the Ministry of Development and Social Inclusion uses school geospatial data to help coordinate a special intervention which provides a bundle of social services (banking, health, and so on; this is known as a 'tambo') to populations in very remote areas. The coordinator of territorial analysis, explained, "When they do an intervention in a 'tambo', and they want to see if there are schools nearby, they can download the education services geolocation information." During the Covid-19 pandemic, the school location data helped locate the tambo centres near student populations so they could be used to charge school tablets and provide vaccinations.

CDEMA reported that they often share data with the **agriculture** sector as many schools in the countries they work with rely on feeding programmes, which require schools to buy food products from local farmers. Geospatial data from both education and agriculture support planning and mitigation measures, helping education workers and farmers to identify which crops will be available for certain schools.

CDEMA also reported coordinating geospatial school data with **emergency and humanitarian** response sectors. In the Caribbean, where schools are designated as natural disaster shelters, thegeospatial school data is shared with national emergency planning units and plays an integral role in disaster response. Giga also shares geospatial school data with countries' emergency response units and globally with the UN Disaster Assessment and Coordination system.

Health was one of the sectors most frequently cited in terms of coordination based on geospatial school data. Several countries mentioned geospatial school data as critical to the education sector's Covid-19 response. In Jamaica, geospatial school data was used to support transportation planning during school closures and reopening and to help determine school reopening in conjunction with data on Covid-19 cases from the health sector.

> **The school maps were integral to the strategic reopening of schools. We collaborated with the Ministry of Health, and we were able to integrate the school maps and COVID-19 cases in communities to determine where the riskiest areas of exposure were for active COVID-19 cases… so we used the school maps to show the communities where we had the highest number of cases of COVID-19. We developed a vulnerability risk model to inform which schools could reopen. The maps were integral to this process; they helped significantly to provide a quick visual look. — Jamaica**

Peru used school geospatial data during the Covid-19 pandemic to determine which schools had facilities, such as electricity, which would enable them to serve as vaccination centres and sites of tablet distribution for remote learning. Critically, the data was also used during the Covid-19 pandemic to determine how to transfer students between private schools with a high probability of closure and nearby open public schools.

In Kenya, the KWTRP uses school map data for several health-related purposes. School catchment area data is used to improve disease mapping through model-based geostatistics (⇡Macharia et al., 2022) and to explore alternative service delivery points. Peter Macharia explained that this is done by “estimating the total population that have access to school-catchments during mass campaigns for health interventions such as bed nets and the Covid-19 vaccine.”

KWTRP also conducts school-based surveys of malaria infection and anaemia prevalence in Kenya and creates school databases to support the sampling process. The results are used to inform school health programmes and delivery of interventions through schools, e.g., deworming. They also work with the national malaria control programme to define the prevalence of malaria and anaemia among school-going children and understand the risk profile. Here, school catchments are used to improve mapping when residence locations of school-going children have not been mapped.

CDEMA and Giga also reported that countries they work with use geospatial school data for health interventions.

In our literature review of geospatial data and school mapping for education decision-making, we identified the same applications as the interviewees reported. The only application that did not come out as strongly in our findings was around workforce management.

4.3 Challenges to using school mapping

As discussed in the previous section, geospatial data is used across a wide range of applications in education. However, countries face a number of challenges in ensuring that school mapping can effectively influence decision-making and impact education outcomes. Factors like the absence of capacity-building strategies, insufficient funding, the limited number of users who can make sense of the data, and a wide gap between evidence and decision-making hinder the benefits of school geospatial data. These challenges are similar to those faced when collecting and analysing geospatial data but are unique to the application of the data for decision-making.

Capacity-building

geospatial data is effective in informing policies that benefit students and teachers when policymakers can understand the data or when other agencies can reuse the data to address other issues. However, for this to happen, school mapping projects and government initiatives must integrate capacity-building strategies.

As mentioned in the first section of this paper, geospatial analysis requires highly **technical skills** that could present a barrier for other stakeholders in using the data efficiently and hinder wider use and collaboration.

> **Databases with geographic information are complex to use, which is why there must be specialised technical capacity to do so, and teams that work across the different areas of ministries. For the National Education Map, an interactive map was developed, which was on the official website, to bring this information to different audiences with an intuitive interface that was more user-friendly – Argentina**

In Jamaica, the GIS unit acknowledges that school mapping could have greater use centrally by other parts of the ministry; however, since there is no capacity in place to optimise this potential, other units might be missing out on important analysis.

> **There are a number of things that the software can do that other units in the ministry could actually utilise. So, it is for us that the only challenge is for us to explore the options, explore the other capabilities of the software, and how we can involve the other units or sections of the ministry; persons can be aware and become familiar, become trained to make certain decisions or having the data here ready, available and in real-time. — Jamaica**

A limitation for the countries is **high staff turnover** in government institutions. Thus, the expertise acquired by staff trained during the implementation of a GIS initiative remains with the individuals and is not transferred to the team or institution. If the trained-up person decides to leave, the organisation lacks the capacity to continue data collection and analysis or use geospatial data for decision-making.

> **The movements within the government institutions sometimes do bring limitation[s], even if you do build capacity when people move out. So, those are the limitations that are often there for managers to really utilise. I think we need to find a way for the government to keep in place people that [are] capacitated - USAID Malawi**

The GIS office in Argentina associates the challenge of the lack of trained human resources with difficulties **integrating data from diverse fields.** The office also highlights that an interdisciplinary approach would facilitate a more holistic response to education issues and even its translation to other areas.

> **Interdisciplinary teams have to be set up with a strong pedagogical component, a strong educational sociology component, a strong territorial knowledge and education component, and one or two other components that have to do with information technology and geographic information systems.**

Building **capacity at the local level** is also important, as it ensures the continuity of an evidence-based approach to education planning and response at all levels of the system. However, a challenge that the Director of Policy and Planning in Sierra Leone faces, is difficulty in decentralising analysis and decision-making because of a lack of technical capacity on the ground.

> **How we can decentralise some of this initiative, you know, in terms of looking at the capacity. They are supposed to be happening at the local or the community level, but we are still handling it at the central level.**

Furthermore, decentralisation of capacity and decision-making also means ensuring on-the-ground capacity to sustain projects locally after the initial funding runs out. Through the interviews, we found that **government agencies struggle to continue school mapping efforts or to update the data regularly once the funding runs out because they would need to hire external capacity to carry it forward**. Local capacity building is fundamental to making these initiatives sustainable. For instance, CDEMA relied on external donor funding for an initial school map effort that ended in 2016 and has not been updated ever since. Similarly, USAID funded the school mapping initiative in Malawi and has not been continued by the Ministry of Education. Finally, Sierra Leone relied on funds from the World Bank to develop the school map efforts.

Funding

Government agencies in Sierra Leone, Jamaica, and the Eastern Caribbean States identify **insufficient funding** as an obstacle to maximising the impact of GIS in the education sector for three main reasons.

Funding is required to collect and analyse school maps, but it is also critical to ensure **comprehensive and frequent training** to continue mapping efforts. In Sierra Leone, for example, the director explained that the development of skills and competencies required to optimise the use of GIS across ministries

> **(…) depends on funding because some of these things might be a challenge to implement, but there is already collaboration in place, there is no issue with that, but the issue has to do with funding. — Sierra Leone**

Moreover, the **high costs of GIS software** represent an additional barrier to the continuity of managing and using school mapping. In Jamaica, for instance, even when the costs associated with capacity building are covered, the main limitation is that the software required is expensive and limited to a few users. For instance, ArcGIS subscriptions can vary greatly based on features needed, support or training required, and customization requests. The official website offers individual "Single Use NonProfit" subscriptions from 100 USD annually; however, ArcGIS Pro's prices range from 1,500 to 8,300 USD per licence.

Finally, funding is required to **maintain databases** over time. CDEMA identifies continuity after a funding project is over as a challenge. Consequently, the databases of some countries in the Eastern Caribbean region have not been updated in more than five years, and GIS offices depend solely on open-source databases to update their maps and justify their decisions. A potential solution could be to involve the community in the data collection process by feeding open-source databases like Humanitarian OpenStreetMap (HOT).[3] However, even though open-source data increases transparency, it also requires

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[3] https://www.hotosm.org/ Retrieved 24 November 2022

verification and cleaning to make it more reliable, as the interviewee from Development Seed explained. Therefore, funding specifically directed towards making school mapping initiatives sustainable over time must include an extra step beyond initial collection and analysis.

Bridging data and policymaking

Once the data has been collected and analysed, there is always the risk that it is not adequately accessible to influence decision-making.

> **[T]here has to be a debate about the link between technology and data and politics, which leads us to a much deeper question regarding 'what is the culture of the world, not only in our countries, to articulate technical knowledge with public policy?' Knowledge is never 100% neutral or 100% technical, and I don't believe that technology will solve everything, and I wouldn't want it [to] either. What has to happen is an articulation between both parts. –Argentina**

Data has to be presented in a way that is clear enough to inform decision-makers when they develop public policies. Evidence from the education sector has shown that GIS is "a powerful tool for public policymaking", as one of the interviewees from Argentina emphasised. However, additional effort is needed to ensure a smooth transition between data and policy. There is still a **lack of awareness** of how impactful geospatial data can be for decision-making. The interviewees from the National Educational Map and the Directorate of Educational Information in Argentina state:

> **There is a huge lack of awareness of this need, there is a lack of people starting to realise all the advantages that the use of geographic information tools and the use of the geolocalised school database can have, the potential that it can have. It seems to me that this is not being exploited as it should be: as a decision-making tool. – Argentina**

Perhaps, people and politicians would be more aware of the potential of GIS, and they would be empowered to use it to make decisions and demand changes in their communities if the data was accessible to them. For instance, the Educational Planning Unit in Jamaica highlights the need for a space to share information and allow stakeholders to use it.

> **Because to be honest, there are some sections or possibly some areas or persons in the ministry who may not realise how useful the school maps are or could be to their analysis, to their work, they're not seeing it. So making it more accessible through some sort of website or dashboard — that would help us. There are decision-makers outside our division that could utilise it way better than just requesting a static map. — Jamaica**

Increasing outreach and diversifying users of GIS data could help close the gap between evidence creation and policymaking. **The formats and mechanisms for sharing and presenting information must be made more flexible for stakeholders at multiple levels** if they are to access and make sense of geospatial data. Jamaica is taking important steps in that direction.

> **I don't think that we have maximised the potential of the school maps or the data that we have. That's something that we're trying to change. Technology is moving very fast, and there are many ways that we can report or analyse them without written reports. In addition, we want to explore that some more and share that wider than the division that we are in. We want to give access to the other regions, departments and the public, making it accessible through a website — some aspects of our school maps. So that potential is yet to be explored. And that's something that we intend to work on. — Jamaica**

5. Impact of school mapping

As discussed in Section 4, governments and partner organisations use geospatial data across a wide range of applications. Reliable, cost-efficient, transparent, actionable data for GIS use allows for a variety of stakeholders to help ensure quality education.These examples and the impact reported by respondents focused on four main areas:

1. Reduction of biases and increased transparency in decision-making, helping to neutralise conflicts among stakeholders and communities.
2. Greater intersectoral collaboration, allowing for more holistic policymaking and coordination with sectors that influence education outcomes.
3. Allowing cost-effective decision-making. Strategically placed resources result in larger populations benefitting from investment in fewer resources.
4. Increased accuracy in the data used to make decisions. Technological advancements allow for more reliable data to make decisions if used in conjunction with local knowledge about the landscape and infrastructure.

5.1 Transparency and equity

Decision-making involving resource allocation, justification for large funding and investments, and risk assessment, among other things, can frequently be influenced by personal and political interests, biases, and misconceptions. Openly available GIS data can allow policymakers, funders, and other stakeholders to act on the basis of evidence, helping to counter bias and corruption. Open GIS data helps to do this by enabling civil society, donors, agencies, and citizens to monitor official reporting and decision-making. As one of the specialists we consulted wondered, “some governments might not want you to paint a certain picture, right?” However, we know data sharing is vital for transparency and democratic and fair decision-making.

Nevertheless, decision-makers might not even realise that their policy and implementation might be based on biases, or incomplete, even inaccurate data and assumptions, which might lead to inequalities.

We knew we needed tools that would help efficiency and also reduce inequities that are existing within the system – USAID Malawi

When data is openly available and presented in a way that is both understandable and actionable for multiple stakeholders, decisions can be more strategic. They can lead to targeted policies focused on equity. For example, Peru uses GIS data from rural school[4] locations to help identify which teachers will receive bonuses as part of a policy to attract and retain teachers in remote areas.

It can also help neutralise politically laden decisions. In Malawi, the school location data was key to shifting power dynamics in charged discussions on where to build new schools. The gap between primary and secondary education enrolment is large due to an insufficient number of secondary schools and the travel time required to reach them. Particularly for girls, gender-based violence (GBV) and long travel distances might make the difference between attending or dropping out of school. So, it was expected that community leaders would request a school in each community; this led to conflicts between community leaders, politicians, and donors. One of the motivators for using GIS was to figure out "how could we tension down the conflict? Based on different power relations that exist, especially around resource allocation."

After digitising, correcting, and delimiting the boundaries of each education zone using GIS, USAID concluded that using the strategic location of schools was more effective and feasible than the previous request. Without considering particularities and special vulnerabilities in each case, the plans to build a school in each community would not solve the issue completely. GIS, however, offered clear data to visualise an abstract problem, solve conflicts, and co-construct solutions to benefit all. With a fraction of the resources, strategically placed schools and resources positively impacted education in the area. Accessible and actionable GIS data ensured resource allocation where needed, the strategic investment of funding, and the provision of access to schools for the most vulnerable.

GIS was very handy in terms of (1) diluting the political pressure on where to build schools and (2) also coming up

[4] The potential location of a rural school is determined on the basis of population density and travel time from the nearest main city to the closest settlement.

with specific locations that make sense that are in great need. So I think that was a very powerful tool for us to use and for the people. People come into a meeting to demand for particular sites based on different interests, but if you use this, this visual [data], people would come to agreement to say, 'I think you're right. I think we need to go to these, all of us who have seen that this is most deserving.' But in the absence of such kind of evidence, it could have been a very difficult task for us to target and also to address those communities that are in great need. — USAID Malawi

Currently, the local government staff is using the outputs of this GIS project to implement more transparent practices based on evidence.

They're using the maps that are outputs from the GIS about structure to inform their supervisions, their monitoring, and to some extent, to rethink how these zones are organised and how they can read the market and inform the demarcation decisions. And also to locate them, when they're distributing some facilities when a new school is coming in. I think they're able to convert some of these products from GIS.— USAID Malawi

More concretely, GIS allowed to strategically locate secondary schools in **Malawi** enabling more students, particularly girls, to access education and bridging the gap between primary and secondary education enrolment.

In Argentina, GIS has made it possible to scrutinise public policies and increase transparency. For example, thanks to geospatial and school attribute data, it was possible to assess the distribution of computers in rural areas compared to that at the national level. Similarly, it allowed to translate inclusion policies targeting foreign students into concrete, measurable data. GIS data has allowed the Ministry of Education to provide additional support to schools with a higher percentage of foreign students to facilitate their successful inclusion in the education system.

5.2 Intersectoral collaboration

The findings from our interviews reveal that GIS data can help illuminate the complexity of educational issues and contexts and promote interdisciplinary collaboration to address them. For instance, when assessing hazards in a school building, CDEMA incorporates data regarding climate change and natural disasters; roads and constructions in the surrounding areas; access to basic services such as drinking water, electricity, or sewage; or information about available crops and their susceptibility to climate change. These and other factors intersect when deciding where to build a school, what type of maintenance is needed, or what school safety plans need to be implemented. For example, CDEMA reported GISbeing used to inform school feeding programmes about crop viability and potential food insecurity.

> **Many of our schools depend on school feeding programmes, for example, and they buy local food crops from farmers. GIS data can assist in terms of what crops will be available at what time, so schools can say: 'Okay, what can we now put on our menu?' Those types of information, I know it's quite broad, but the GIS data can certainly assist the education sector in planning ahead and also in mitigation measures – CDEMA**

Disaster risk reduction and preparedness also involve the collaboration of multiple agencies, which rely on accurate and up-to-date GIS data. For example, flooding has been an issue for many years in St. Lucia. However, GIS data shed light on mitigation measures that could be put in place to effectively use drainage systems. The initial funding came through a World Bank project and is now being executed by the Ministry of Economic Development; this has, as a result, benefitted schools and decreased the number of days out of school due to flooding.

> **So not just the school now is benefited, but the community which is right there on the coast also suffers from erosion from the sea as well as high tide and flooding and so on. So, the GIS was used, and they were able to conceptualise a flood mitigation measure through drainage. We have seen a reduction in the amount of flooding that has happened at this educational complex. — CDEMA**

Therefore, more concretely, through a close collaboration among national, regional, and international stakeholders, CDEMA is able to run a multi-hazard GIS model. It incorporates school locations with distance to main roads, rivers and flash flooding risks, and slope risk among others to identify the specific hazards that threaten schools in the Eastern Caribbean region. This allows CDEMA to collaborate with multiple agencies and stakeholders to tailor disaster risk reduction plans to each building in at least three participating countries, with the intention to include three more countries in the next six months. The national plans so far include maintenance work needed based on school location and vulnerability, evacuation and disaster response plans, and education and feeding program continuity during disasters. This information is also being used to inform teacher professional development courses to increase teachers' capacity to respond to school-specific hazards.

Similarly, in Sierra Leone, the Ministry of Energy, Ministry of Water Resources, Ministry of Agriculture, Ministry of Gender, and the Ministry of Social Welfare for Child Protection are using school data to develop gender equity and protection strategies for schools and students. "So yes, of course, we have a lot of interventions from other nine ministries." This level of collaboration allows for a joint effort to tackle complex issues that affect the education community.

Jamaica provides another example of the impact on education due to collaboration among sectors. The Ministry of Education and Youth shares GIS data on schools with telephone companies to help solve connectivity issues and ensure access to online learning.

5.3 Cost-effectiveness

GIS data can help allocate existing resources more efficiently and effectively and support smarter investments. For instance, Development Seed explains how AI models can work with large datasets more accurately and effectively, in less time, and with open-source data. Even though human corroboration is still required, the speed and accuracy of the model allow for mapping a wider area.

> **Compared to a year or two ago, there have been a number of advancements; newer model frameworks are quicker, more accurate. There are just completely different new ways to handle a larger amount of data now. — Development Seed**

Reducing costs is fundamental to effectively implementing at-scale education projects. Saving data collection and analysis resources could mean having more resources available for other projects. CDEMA shared their experience of yet another advantage of

GIS during the pandemic: working remotely, assessing risks, and planning implementations without spending money on travelling or accommodation.

On the other hand, in Sierra Leone, school mapping helped lead to a shift from distance-based aims to a needs-based strategy. This was evidenced in the School Infrastructure and Catchment Area Planning Policy published in 2021. During policy development, research using school mapping revealed the costs and challenges associated with building schools in areas with low population densities, especially at the secondary level where subject specialists are needed. For instance, the analysis estimated that constructing and running a junior secondary school within 3 miles of every pupil would cost USD 1.6 billion – many times the overall annual education budget – and that a more effective policy would be to focus on where best to utilise the resources that are available.

Finally, school mapping in **Kenya** promoted convenient and cost-effective sampling of diseases in schools to define the prevalence of malaria and for anaemia among school-going children.

> **Since 2009 we have undertaken school-based surveys of malaria infection and anaemia prevalence in Kenya. This is used to inform school health programmes and delivery of interventions through schools e.g., deworming. Also, to understand the risk profile, i.e., the exposure (where they come) from relative to where they go to school. For sampling purposes, it is critical that we define the universe of all schools in Kenya. Hence, creating databases of schools for sampling purposes of school-based malaria surveys (…) The universe of all schools is used to create sampling points. Schools as a sampling point are convenient, cheaper, and more efficient. — Kenya**

5.4 Accuracy and reliability

To deliver high-quality education and address equity issues, accurate and reliable geographic information about schools and related attribute data is essential. Additionally, by knowing where schools are located, governments and international organisations may better understand the needs of more susceptible communities and be better prepared to deal with external shocks like disease outbreaks or natural catastrophes. However, this type of data is frequently inaccurate or non-existent.

The recent advancement of computer algorithms, visualisation programmes, and open-source software has allowed for faster, more efficient, and more robust models to handle large datasets. In Malawi, for instance, without the accuracy of GIS, according to the USAID representative delimiting boundaries, mapping infrastructure, and allocating resources in response to the varying needs of each region would have been “impossible”. Moving from drawn maps to digitised zones corroborated on the ground represented the first step towards a more equitable distribution of resources. Reliable data that reduces human biases points decision-makers towards the areas in most need.

> **For us, it was a tool that enhanced efficiency in terms of coming up with where to intervene. — USAID Malawi**

Using AI, as part of GIS to identify unmapped schools, has the potential to “map every school on the planet” (⇡Development seed, 2021). In collaboration with UNICEF, Development Seed has identified unmapped schools across eight countries in Asia, Africa, and South America. Using an AI model, Development Seed has analysed high-resolution satellite imagery, run an algorithm for detecting structures that are likely to be schools, and flagged those schools for human evaluation. This method allowed them to map 23,100 schools in under seven months, with a precision rate of more than 0.89 in all cases. Precision enables us to see the machine learning model's reliability in identifying the model as positive. Among those buildings identified as schools, around 6% of them are considered false positives.

This level of precision and speed could only have been achieved thanks to the reliability and accuracy that GIS analysis brings. However, the use of these advanced technological methods also requires contextualised validation due to the architectural differences across countries and urban and rural sectors. While the AI model used by Development Seed successfully maps schools across different regions, landscapes, and architectural styles, it should always be used with stakeholders familiar with the local area. In addition to local corroboration of GIS data, there is also an opportunity to draw on open-access data to complement formal data collection efforts and help avoid duplication.

> **AI can be used to identify potentially unmapped schools, but should always be part of a bigger feedback loop that uses humans to validate and add context. You'll always want to verify those schools are actually being utilised. But AI provides a big step in getting buildings on the map. — Development Seed**

6. Enablers of effective use of GIS data for decision-making

After the difficulties of data collection and analysis have been addressed, and countries and organisations finally have accurate and reliable GIS data, another challenge remains: leveraging the data to inform decision-making. This section explores enablers that allow stakeholders to transform data into evidence-informed actions. For GIS to be an effective tool for decision-making, a few critical conditions must be met. These include usability, availability, and contextualisation.

6.1 Usability

Usability and 'friendliness' of the data format, among other things, are factors associated with the effective use of GIS data for decision-making in the education sector. For instance, presenting the data in a relevant way that makes sense to all stakeholders allows for a larger population of stakeholders to interpret and use the data to address a specific issue. USAID Malawi used GIS outputs and presented them as accessible maps to the community to help solve conflicts and collaboratively identify the communities that most needed resources in Malawi. Similarly, he found that GIS was a valuable tool to enable decision-making, even remotely, when transformed into actionable and user-friendly formats.

> **GIS brought in precision in terms of targeting and also is something that brings visuals — [it] is something that is real. Sometimes it's difficult to just work on data or numbers. GIS brings that reality even if you're in an office, it brings you to the site that we're looking at. — USAID Malawi**

When GIS data is accessible and interactive, it allows stakeholders from multiple backgrounds to understand and act on evidence. For instance, in Argentina, how school maps were presented allowed stakeholders from multiple backgrounds to understand them and reach conclusions. This is not always the case with databases; their use is often restricted due to the high levels of technical skills required to use them and interpret data.

> **There are maps that are in PDF; they can be downloaded by anyone, anyone can use them. On the interactive map, you**

can choose the variables you want to use from the schools; you can select. For example, rural schools, primary schools, kindergartens, you can make a lot of selections, and it makes the map very intuitive; let's say anyone can use it, anyone who has already gone through the literacy process, let's say they know how to read and write, let's say any child can handle this map. — Argentina

Similarly, in Peru, the GIS department is working towards transforming GIS data into outputs that can show the public the potential of this data.

You have to produce analysed data because users are not really going to understand beyond seeing the little dot on the map what they can do with the data; it's until you start producing things that people say, 'Ah, look at this, all this we can do!' — Peru

For large-scale school mapping exercises and those that use AI, like the one led by Development Seed, contextualisation is another element required for the data to be reliable and effective. The data should be corroborated by local stakeholders and incorporate the infrastructure characteristics of the region.

6.2 Availability and openness

GIS initiatives that rely on and promote open-source data and involve multiple stakeholders in data collection are sustainable over time. For instance, in the case of several Eastern Caribbean States, data collection from scratch represents a large investment that cannot be made at this moment. However, open-source data like Humanitarian OpenStreetMap and other similar initiatives have made it possible for the Eastern Caribbean States to update their data regularly and use it to plan disaster and risk reduction plans in schools.

Furthermore, openly available data also allows community members to make sense of the data, make the data collection and maintenance efforts more sustainable over time, and use the data as a tool for solving conflicts and evidence-based decision-making. For instance, when methods to collect GIS data are user-friendly and open to all, neighbours can report road obstructions that might affect school access. Similarly, educators, students, and parents can report hazards in the school area not identified during the initial data collection using geolocation pictures. Hazards identified in the initial school mapping might have changed, and new hazards might have appeared. These databases could be sustainably updated if the community was involved. This community approach is starting to be explored by CDEMA in six countries in the Eastern Caribbean region.

7. Conclusions

Data from five country governments, one regional agency, one international initiative, one implementing partner and one private entity, all using GIS for education decision-making in Latin America, the Caribbean, and sub-Saharan Africa, wereanalysed for this study. We explored how these stakeholders collect, analyse and apply data in the education sector; the challenges they face; the impact on the education sector; and a set of enablers for the effective use of GIS. Please refer to Table 1 for a summary of the data collection methods and use for each stakeholder we interviewed.

Although the decentralisation of educational systems is occurring in many nations worldwide, school mapping remains the central government's remit in the countries studied. The primary source of information for the departments responsible for collecting the data is the school census or the list of registered schools, which typically capture the geolocation or the schools' addresses; these can then be added to the school maps. The main users of such maps were international organisations, development partners, and ministries of education. The many offices and organisations that work with school maps have recognised various difficulties associated with data collection and analysis, such as technical capacities, data accessibility, software limitations, funding, and information protection.

Participants reported using school data for various objectives, which fall under two broad application areas. The first is education planning, particularly regarding resource allocation and infrastructure. The second is cross-sector coordination, particularly regarding health and emergency services, allowing for a more holistic approach to facing education challenges. This kind of coordination is also an opportunity for the education sector to learn from other sectors, like health, on the benefits of up-to-date GIS data for decision-making. However, in their application of GIS data, stakeholders faced three main challenges related to (1) capacity building, (2) funding, and (3) bridging data and policymaking.

Table 1: Summary of stakeholder data collection methods and use of school maps

Country /Region	Data collection method	Use
Argentina	Addresses and/or spatial references of schools collected in the school census are input manually in a GIS software	Allocate devices in rural schools Identify regions to promote children enrolment campaigns in pre-primary Identify proximity of schools to social services
Jamaica	During the school census the geographic coordinates are collected and for new schools a team is sent to each new school building to collect coordinates	Identify proximity of schools to social services Determine school reopening schedule based on the area's COVID-19 infection rate
Kenya	Includes geographic coordinates with a survey about the state of the buildings, data about teachers and students ratio, and health indicators	Catchment area planning to improve disease mapping and explore alternative service delivery points Develop isochrone maps to measure actual walking distance to meet the national travel thresholds Collect data for public health threats in schools like Malaria and Anaemia and deliver health interventions
Malawi	A field team was sent to schools to collect geographic coordinates and update the former maps	Identify best locations to build new schools Develop isochrone maps to measure actual walking distance between schools and teacher development centres Monitor coaching interventions and its effect on literacy performance
Eastern Caribbean States (CDEMA)	1. Aerial photography 2. Satellite imagery 3. Geographic coordinates of schools on the ground	Disaster and risk reduction Collaborate with the agriculture sector to inform school feeding programmes
Peru	1. Geolocate schools manually using addresses 2. If it cannot be located, a team travels to the building to collect the coordinates 3. Starting to use a mobile app to locate new schools in remote areas and validate former geolocations	Improve management efficiency Identify proximity of schools to social services Identify schools that match the requirements to serve as vaccination centres and charging stations for school tablets
Sierra Leone	During the school census efforts, geographic coordinates	Resource allocation Assess connectivity to tailor remote learning

	were collected with location-enabled mobile devices	alternatives School Infrastructure and Catchment Area Planning Identify climate-smart areas to build new schools

There are several key impacts that the use of school mapping and GIS initiatives are having on the education sector. The effective use of GIS data has been shown to (1) improve the accuracy and reliability of the data needed to make decisions, (2) promote transparency and equity, (3) enable intersectoral collaboration, and finally, (4) make ongoing work and initiatives more cost-effective. The direct and concrete effects of GIS data-informed decision-making can be seen in the number and location of schools built in Malawi, in the Covid-19 response planning in Jamaica, in the school infrastructure and catchment area planning in Sierra Leone, the creation of safe education plans in the Eastern Caribbean region, and the convenient and cost-effective sampling of disease in schools in Kenya.

There are also key enablers for using GIS to more effectively impact the education sector and promote evidence-based decision-making. Among the enablers we identified are ‘usability’ and ‘availability and openness’, including contextualisation of processes and methods to collect and analyse GIS data.

8. Recommendations

Based on the data we collected from specialists across Latin America, the Caribbean, and Africa and the experience of international organisations like Giga, Development Seed, and USAID, we make the following recommendations for using GIS in education.

- **Make GIS data accessible and easy to understand:** One of the primary obstacles faced by GIS specialists is making GIS data accessible to ministry officials and technical staff, simple to comprehend, and easy to use for all those who need to use it. Highly technical and expensive software is required to perform GIS analysis, which might exclude policymakers and community leaders, hindering evidence-based decision-making. Although there are open-source and free software, most offices we interviewed used the paid software. There is a gap between the information generated by GIS specialists and how it is processed by policymakers; moreover, there is data generated that is not used because of the way it is presented as well as repetitive data requirements from policymakers due to the difficulty to access information. To date, efforts have focused on developing information-providing platforms; nevertheless, it is still necessary to develop mechanisms whereby data may be used without the requirement for GIS expertise. CDEMA, for instance, confirms this challenge:

  > **So, I think that information needs to be broken down and put into — if I can use common language —[so] that business can understand how to use it. — CDEMA**

  Jamaica also mentioned that creating a more user-friendly presentation for GIS data, such as a dashboard that the wider ministry can access, would support the usability of the data. Therefore, one of the key recommendations from multiple interviewees is to work towards more user-friendly outputs of GIS analysis.

- **Provide guidance and capacity building for using GIS data:** Engaging stakeholders in capacity development to use GIS data is essential. The first step is a shift in perspective to understanding how powerful GIS data can be in influencing decision-making, followed by allocating resources and creating a plan based on assessing capabilities and needs at the country level. This is also key to ensuring the data can be used by a diverse set of stakeholders and for cross-sector coordination.

> **The Minister of the government has been doing a lot of training; they are expanding the training across the ministry. That's not just the Ministry of Education, there are other ministries that are government agencies that are being trained to use [the GIS data], and then eventually, once the capacity is built, then we can expand. — Educational Planning Unit, Jamaica**

> **Across government, there has been growing interest in GIS training. Persons are undertaking courses to familiarise themselves with GIS mapping. It is not just the Ministry of Education and Youth, there are other ministries that are government agencies that are being trained to use [the GIS data], and then, eventually, once the capacity is built, I believe we can expand. — Educational Planning Unit, Jamaica**

The IIEP had developed new tools and approaches that revolutionise the use of school location data into educational practises in order to provide guidance and build capacity. These tools are plug-ins for qgis designed to estimate the school-age population at the local level, to conduct school placement multi-criteria decision analysis (MCDA), and to increase access to schools with isochrones as catchment areas, among other things (⇡UNESCO IIEP, no date).

- **Undertake more targeted cross-sectoral collaboration:** The findings from our interviews confirm that GIS data can help illuminate the complexity of educational issues and contexts and promote interdisciplinary collaboration to address them. School mapping can also support critical outcomes in other sectors, such as health and emergency response. It is, therefore, essential to coordinate data sharing across sectors for improved decision-making.

> **Have ALL actors at the same table, discuss the evidence and draw a course of an appropriate action**

> **or follow-up, especially for school health programmes, to improve our understanding of social determinants of health and learning outcomes in school-going children — KEMRI**

- **Enhance communication between the stakeholders:** Lack of communication between all participants is a widespread issue in the development of both geographic and statistical data, resulting in redundant data collection or analysis, as well as a waste of both economic and human resources. Promoting a culture of data sharing would help decrease duplication of efforts.

> **When you're dealing with siloed data, data that is not in the public domain, it's the lack of communication of who is collecting data on the one side and who is collecting data on the other side. There's potential for both gaps and duplication. — Development Seed**

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Appendix

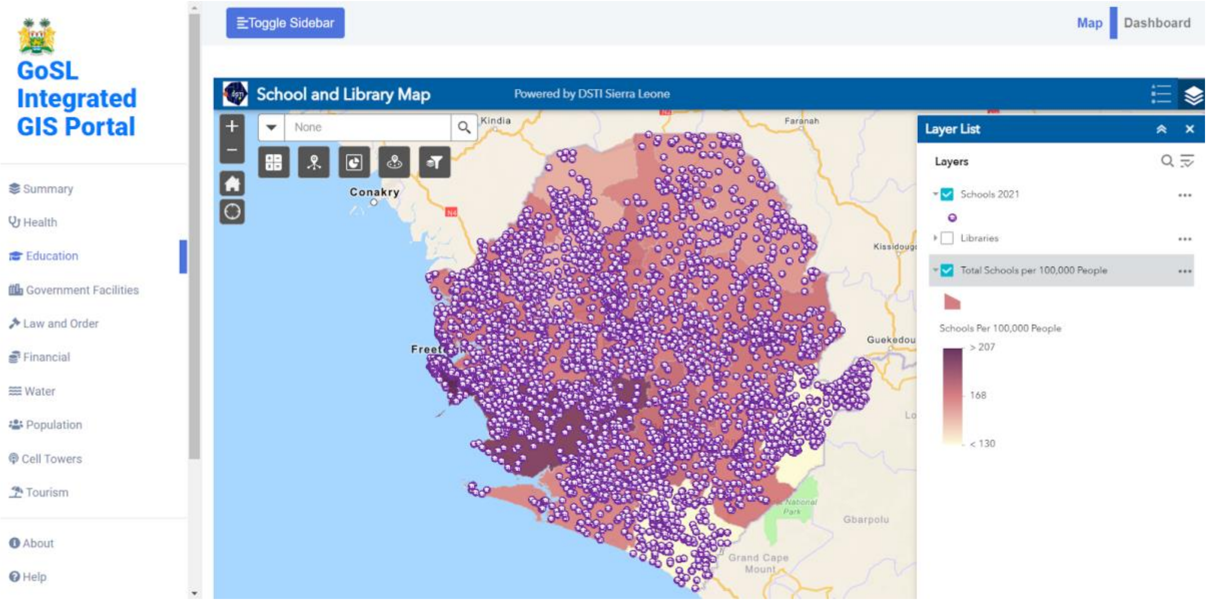
Appendix 1. List of interviewees

- Argentina: Maria Alejandra Sendon, Director de Mapa Educativo Nacional, Dirección de Información Educativa / National Educational Map, Directorate of Educational Information
- Caribbean Disaster and Emergency Management Agency (CDEMA): Renee Babb, GIS specialist and head of the GIS department of CDEMA; Bernez Khodra, Senior Programme Officer, Safe Schools at CDEMA
- Development Seed: Kathryn Berger, Machine Learning Engineer
- Giga: Dohyung Kim, Lead Data Scientist, UNICEF
- Jamaica: Melissa Lunan-McTavish, Assistant Chief Education Officer, and Rashida Green, Education Planner, Educational Planning Unit, Ministry of Education and Youth
- Kenya: Peter Macharia, PhD, (Spatial epidemiologist) Population Health Unit, Kenya Medical Research Institute (KEMRI) — Wellcome Trust Research programme (KWTRP)
- USAID Malawi: Kondwani Nyirongo, Program Management Specialist
- Peru: Claudia Lisboa, Director of the Statistics Unit, and Amalia Sevilla, Coordinator of Regional Analysis, Unidad de Estadística, Ministerio de Educación / Statistics Unit, Ministry of Education
- Sierra Leone: Adama Jean Momoh, Director of Policy and Planning, Ministry of Basic and Senior Secondary Education

Appendix 2. School maps

Sierra Leone

The Integrated Geographic Information System (GIS) Portal is an interactive and public platform that connects different GIS datasets from the Government of Sierra Leone (GoSL) and its partners. The platform will let people in charge of decision-making see and use data from schools, hospitals, government facilities, and natural resources, among others. The school data available consists of the EMIS code, school type, ownership, approval status, total enrolment, accessibility, year of foundation and GPS.



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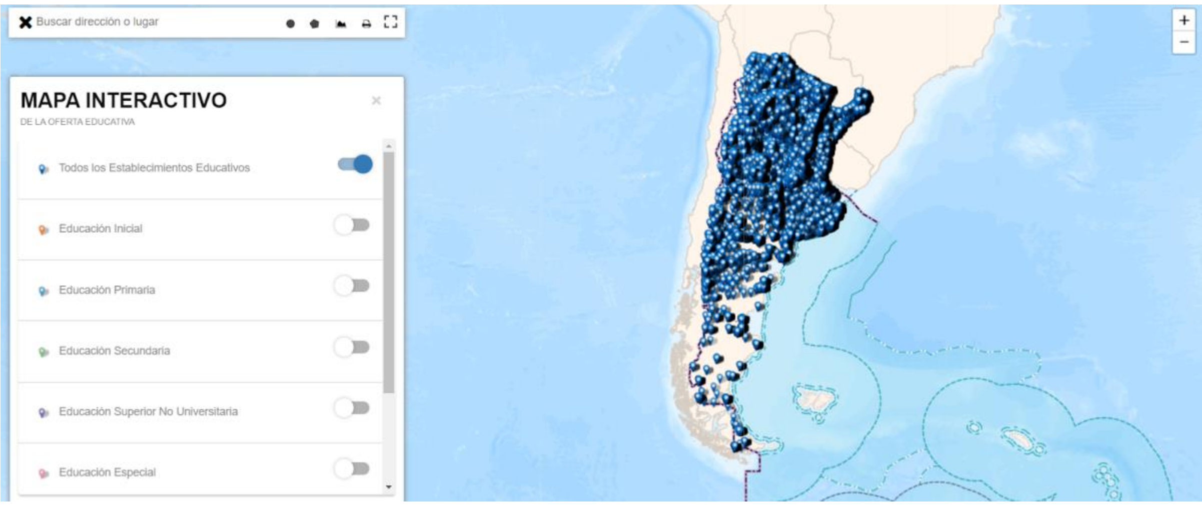
Argentina

The 'interactive educational map of Argentina' is a public, interactive map that allows the user to filter by level and includes, among other geographic information, the name, location, and postal code of certain schools.



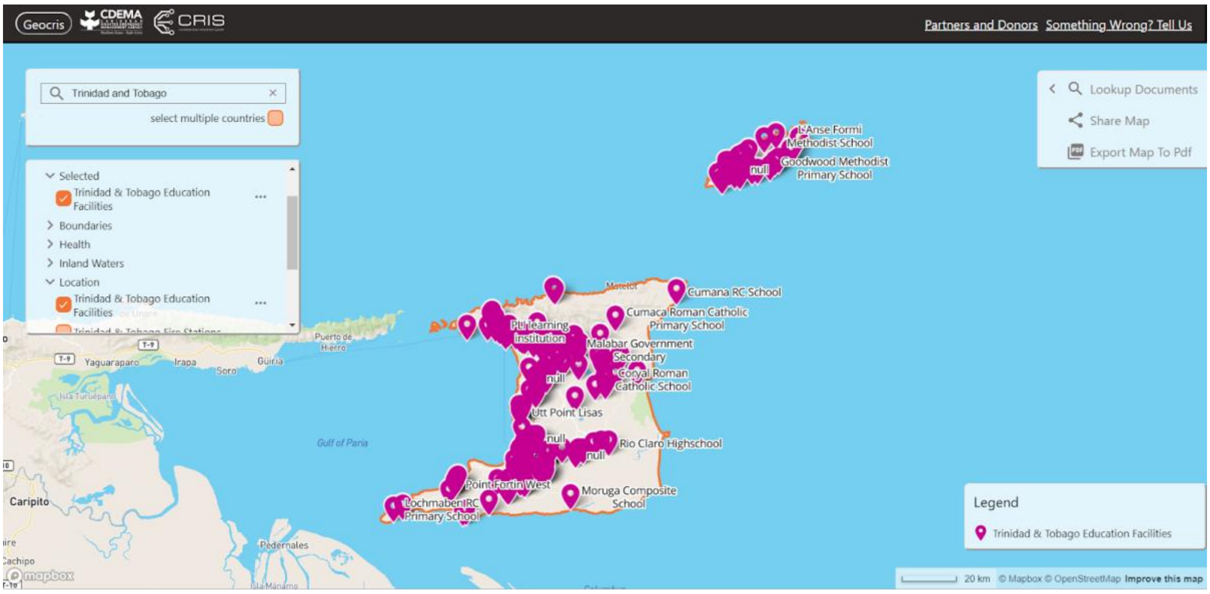
https://mapa.educacion.gob.ar/mapa-interactivo Retrieved 24 November 2022

Jamaica

The school map of Jamaica was shared with the authors via Google Earth and is not available publicly. The following data is available for every school: School name, school level, total enrolment, capacity, ownership, geographic information, contact information and year of construction.

CDEMA

The GeoCRIS is an interactive map from the Caribbean Risk Information System (CRIS). GeoCRIS gives access to geographic data essential for risk and hazard mapping, in addition to emergency preparedness and response operations. The GeoCRIS is a collection of information from all countries of the region, gathered from both public and member-provided information sources. The data available for each country varies from one to the other.



CDEMA Geocris: Find geospatial data for all CDEMA member states[5]

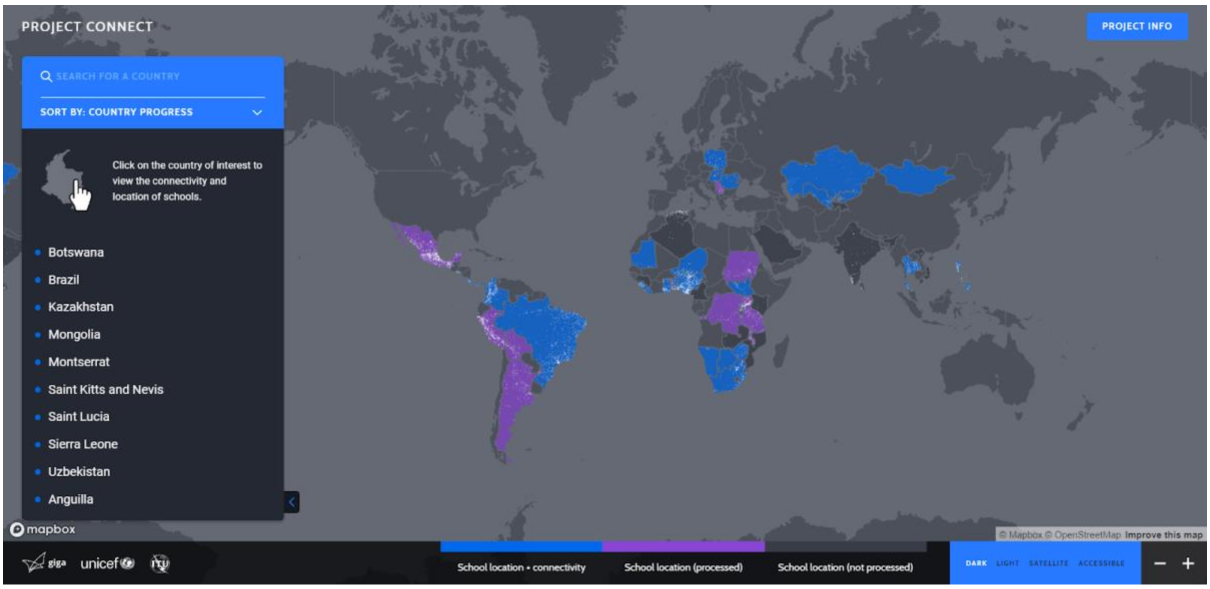
[5] https://geocris2.cdema.org/ Retrieved 24 November 2022

Peru

The ESCALE (Educational Quality Statistics) website is a tool that provides detailed information on registered educational institutions throughout Peru and a wide range of statistical data on the education sector.

Giga

UNICEF is mapping the location and internet connectivity of every school in the world in real time. This map, which is hosted on an open data platform, is helping governments and other organisations around the world close the digital divide. Over 900,000 schools in more than 35 countries have been mapped so far, and that number is growing quickly. The map shows the connectivity for each school and the name of the school.



[Project Connect (unicef.org)](https://projectconnect.unicef.org/map/)[6]

[6] https://projectconnect.unicef.org/map/ Retrieved 24 November 2022

Appendix 3. Interview guide

Background

1. Could you please describe your role for us?
2. What is your office / department responsible for?
3. How is your department connected to school mapping activities?
    a. Does your department work with other departments or agencies on school mapping?
    b. How long has your department or government been using school mapping?

Data Collection & Analysis

4. Does your department or government collect geospatial school data?
    a. If yes, please walk us through the data collection process
        i. Who is involved? (To understand sustainability of process)
            1. Do they hire specialists who do this occasionally, or is it integrated into the regular assessments?
            2. Are school principals / MoE staff trained to collect the data?
        ii. What tools are used?
            1. Do you use remote sensing and / or GPS tracking?
            2. What is the format of the data (website, platform, spreadsheet)?
        iii. What are the high-level steps in the process?
        iv. Do you have a differentiated collection method for new schools, or is it available in the school map until it is collected for new schools?
        v. Is the data updated on a regular basis? If yes, how often?
        vi. What are the challenges at this stage?
    b. If no, who collects the data? An NGO or third party that is hired?
        i. Who is involved and what tools are used?
        ii. What are the high-level steps in the process?
        iii. How is the data shared and hosted between the government and the other organisation?
5. How does your department analyse the data?
    a. Who is involved and what tools are used?

Data Use & Interpretation

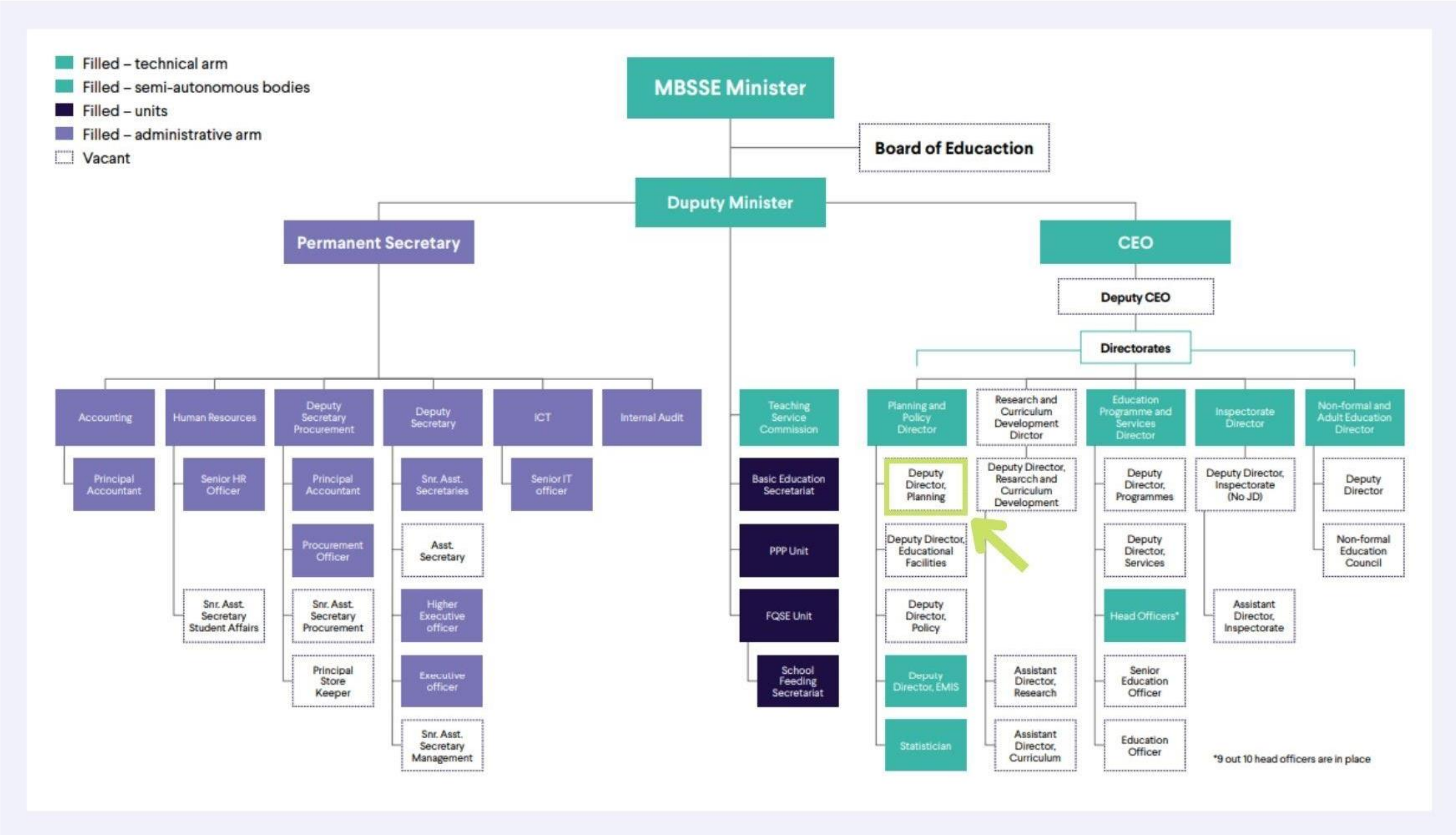
6. Is the data publicly accessible or used only internally?
    a. Is there some data that is publicly available and some that is just used internally? Why?
7. What does your department use the data for?
    a. Are you aware of any other organisations or government departments that use it?
8. What do you think this data has told you about the education sector?
9. Is the data really informing decision-makers about what is currently happening in the education sector? In what ways?
10. Could you help us better understand how the data is translated into concrete actions? For example, can you remember an instance where school mapping, particularly GIS data, was used to inform a school building project, to assess risks, or to allocate teachers?
    a. What do you think makes it difficult to translate this data into action? What would make it easier?
    b. What do you think has facilitated this? What are 'good practices' to replicate in terms of school mapping and decision-making?

Appendix 4. Qualitative analysis codes

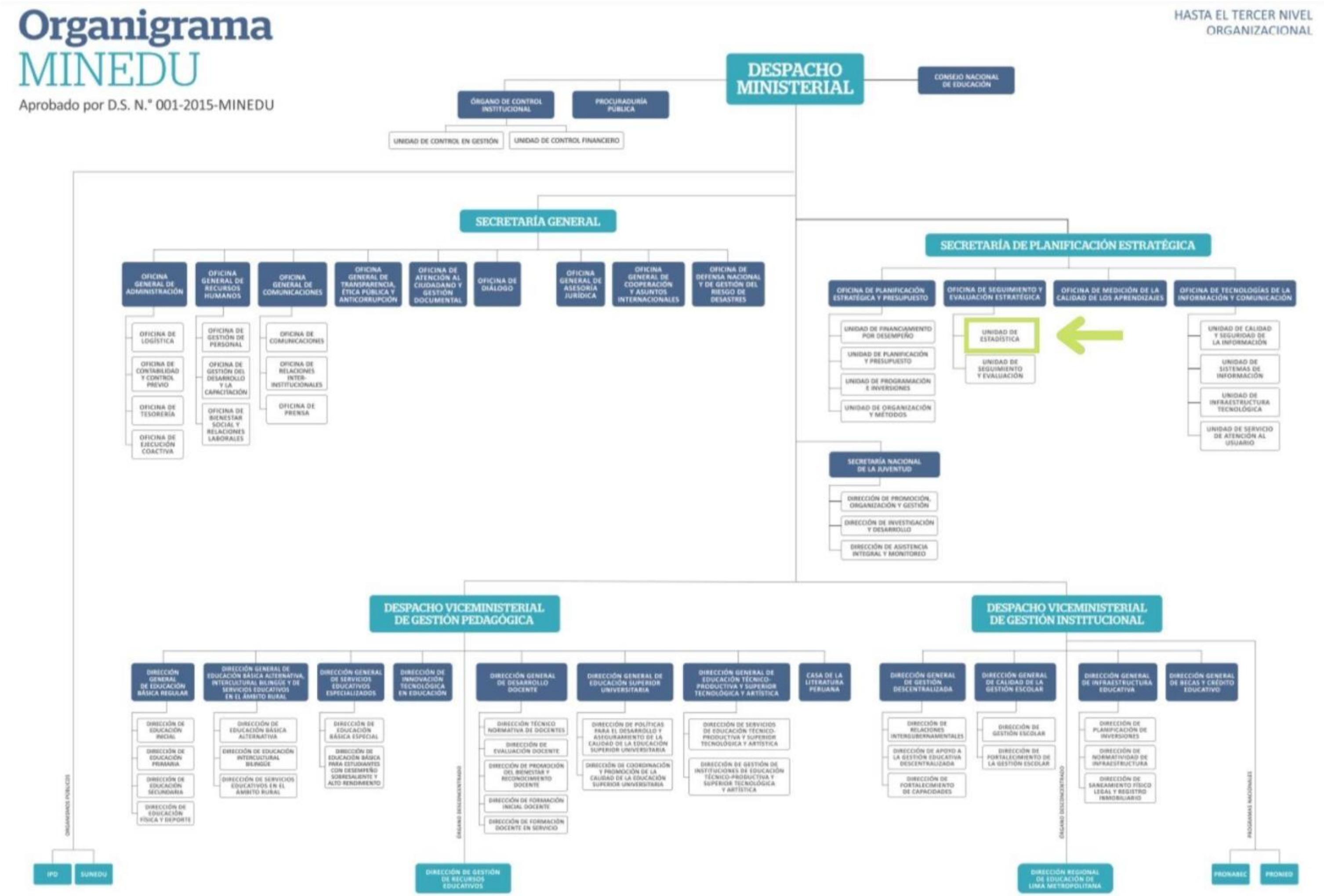
- **Application**
  - Disaster Risk Reduction
  - Social services
  - National planning
  - Enrolment
  - Teachers
  - Challenges
  - Health
  - Transportation
  - Infrastructure
  - Isochrone maps
  - Resource allocation
  - Cross-sector collaboration
  - School feeding program
  - Internet/connectivity
- **Data collection and analysis**
  - Process
  - Software
  - Format
  - Open data
  - Data collectors
  - Background
  - Data security
  - Challenges
- **Users**
  - MoE HQ
  - Implementing partner
  - Regional/District officials
  - Schools' operations dept
  - Health sector
- **Impact**
  - Cost-effectiveness
  - Transparency
  - Reliability
  - Enabling decision-making

Appendix 5. Organigrams: Organisational structure of the school mapping department

In the case of **Sierra Leone**, the Ministry of Basic and Senior Secondary Education (MBSSE) addresses all school-mapping related tasks through their deputy director, on the planning department (marked in gree). Sierra Leone has mainly used school maps to allocate resources, create isochrone maps, and deploy teachers. This organigram is in place since 2019.



Peru houses all work related to school mapping in the statistics unit within the office of strategic monitoring and evaluation (marked in green). These maps have been used to identify possible vaccination centres.



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