General Triangulation Guidance

National Level

1

In-depth introduction to triangulation principles and the 10-Step process for National and Regional/Provincial levels

World Health Organization, UNICEF, & U.S. Centers for Disease Control and Prevention

TRIANGULATION FOR IMPROVED DECISION-MAKING IN IMMUNIZATION PROGRAMMES

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1. Introduction

1.1. Data Use for Programme Improvement

The Immunization Agenda 2030 has highlighted "data-guided" as a core principle to recognize that successful immunization programmes use data to guide efficient management, tailor strategies, and make decisions to achieve programme goals. Many data sources are generated within and outside the Expanded Programme on Immunization (EPI) (e.g., routine administrative data, coverage surveys, programme targets, vaccine supply, programme management, surveillance, serosurveys). However, use of various data sources together is not optimal. As such, the Strategic Advisory Group of Experts on Immunization (SAGE) has recommended **increasing use of existing data for tailored action and decision-making**.[1]

The limitations of vaccination coverage data quality have been discussed as a challenge to data use. However, evidence shows that increased use of data results in improved data quality, but not necessarily the other way around.[2] Even in the absence of perfect data, public health practice has long acknowledged that **combining many pieces of weaker evidence through triangulation can form a strong basis for more informed decision-making**.

In 2019, the SAGE Working Group on Immunization and Surveillance Data Quality and Use suggested that triangulation should be the standard for public health analyses and recommended to develop triangulation guidance for use at the national and subnational programme levels.[3] Many public health practitioners will discover when reading this guide that they routinely do triangulation, without knowing it. The **aim of this guide is to outline a more systematic and rigorous approach to triangulation towards the goal of refining EPI practices and improving outcomes**.

History of Triangulation

The term "triangulation" started in surveying and navigation as a method to determine location using two reference points. Since the 1970s, triangulation has been used for social and health science research. Public health use of triangulation increased in the early 2000s, including to assess disease burden and monitor programme impact. A robust approach to "public health triangulation" has been developed by global HIV/AIDS programmes, which is a basis for the present triangulation guidance.[4,5,6]

[1] World Health Organization. Meeting of the Strategic Advisory Group of Experts on Immunization, October 2019: Conclusions and Recommendations. Wkly Epidemiol Rec 94 (2019).
[2] Immunization Data: Evidence for Action (IDEA). A Realist Review of What Works to Improve Data Use for Immunization, Evidence from Low- and Middle-Income Countries. Seattle: PATH; Washington, DC: PAHO; 2019. https://www.technet-21.org/en/topics/idea
[3] Report of the SAGE Working Group on Quality and Use of Immunization and Surveillance Data (2019): https://www.who.int/immunization/sage/meetings/2019/october/presentations_background_docs/en/
[4] Rutherford et al. Public health triangulation: approach and application to synthesizing data to understand national and local HIV epidemics. BMC Public Health. 2010;10:447. https://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-10-447
[5] UNAIDS. An Introduction to Triangulation. Geneva: UNAIDS; 2010. https://www.unaids.org/sites/default/files/sub_landing/files/10_4-Intro-to-triangulation-MEF.pdf
[6] World Health Organization (WHO). HIV triangulation resource guide: synthesis of results from multiple data sources for evaluation and decision-making. Geneva: WHO; 2009. https://globalhealthsciences.ucsf.edu/sites/globalhealthsciences.ucsf.edu/files/pub/gsi-tri-oms-hiv-triangulation-guide.pdf

1.2. What is Triangulation?

This guide defines triangulation as the **synthesis of two or more existing data sources to address relevant questions for programme planning and decision-making**. Triangulation can include assembling the data together in one graph or stitching information from several graphs together with a narrative thread. Triangulation requires critical thinking and some basic analysis skills, but the activity goes beyond making graphs — it's about turning data into reliable information for action.

Through the use of multiple data sources, the triangulation process identifies and addresses the limitations of any one data source and/or data collection methodology. A more complete view of the programme issue can be obtained by making sense of complementary information and integrating knowledge of the broader context (Fig 1).

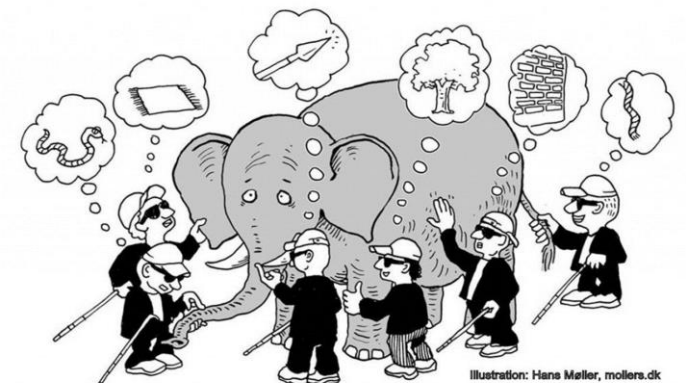


Fig. 1. Triangulation is like the parable of the blind men and the elephant. The process enables staff to obtain a more complete view of the issue by examining and summarizing data from multiple sources and perspectives.

1.3. What Triangulation is NOT

This document provides guidance on triangulation of *existing* data for programme improvement. Based on our definition, **collecting additional data or presenting different graphs, without synthesis and interpretation**, is not considered triangulation. Other research methods and data collection activities might be better suited for particular programme questions, e.g., surveys or focus group discussions to identify behavioral determinants of vaccination.

For the purposes of this guidance, data triangulation is *not* **meta-analysis or other defined research and evaluation methods.** Examples are field-based assessments of immunization data quality (e.g., Data Quality Self-Assessment) that re-tally the primary source data and compare with reports at various levels. In this case, additional data collection is involved, and the data originate from the same, rather than different, sources; however, this may represent a form of *investigator triangulation*.[7]

1.4. Monitoring Framework for Triangulation

EPI data triangulation relies on knowledge of the **underlying theory** of how the immunization programme should be implemented in order to deliver vaccine to the target population and achieve the goal of reduced VPD incidence, deaths, and inequity. Using a **monitoring framework** helps identify indicators along the chain of events and confirms the need for synthesis of data from multiple sources as part of data-guided immunization programme management (Fig 2). Triangulation

[7] Four types of triangulation have been described: data triangulation, methods triangulation, investigator triangulation, and theory triangulation. For more information, see UNAIDS Introduction to Triangulation (2010).

can be used to address various questions across this framework to guide planning, strategy and policy from vaccine introduction to programme management to verification of disease elimination.

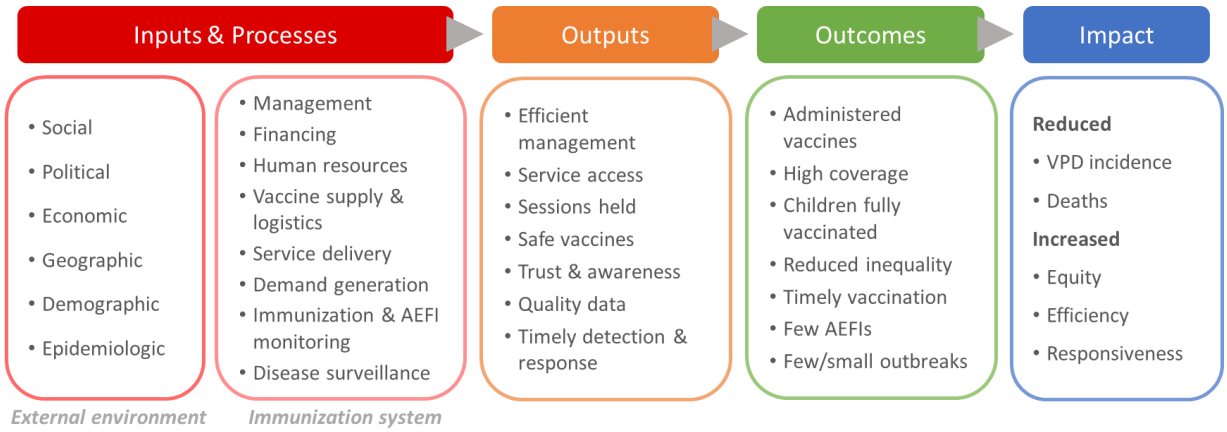


Fig. 2. Monitoring framework for immunization and vaccine preventable diseases. The framework shows how inputs (e.g., human resources) and processes (e.g., vaccine supply chain) are reflected in outputs (e.g., service access) and eventual outcomes (e.g. vaccination coverage) and impact (e.g., reduced VPD incidence). Adapted from other sources.[8,9,10] AEFI=adverse events following immunization, VPD=vaccine preventable disease.

1.5. Examples of Triangulating Immunization Data

Examples of triangulation include everything from pen-and-paper comparisons of coverage figures (e.g., administrative reporting vs. survey) to complex modeling of coverage or disease burden. A review of different uses of triangulation by EPI at different levels categorized examples into **five common analysis objectives** (Table 1).[11]

An example of triangulation use as a *consistency check* of reported numerator, denominator, coverage, and vaccine stock-out data is shown in Fig 3. A risk assessment is an example of using triangulation as a *diagnostic to target programme interventions*, which may be useful for predicting risk (Fig 4). Triangulation methods can also be used to *estimate coverage, target populations, or disease burden* as shown in the subnational coverage estimation exercise in Fig 5. *Evaluations of the effectiveness or impact* of immunization programmes and immunization activities often use triangulation to integrate different information (Fig 6). Triangulation can also be used for *holistic assessments of programme adequacy*, such as the process of verifying measles and rubella elimination (Fig 7). Other uses of triangulation are also possible.

[8] International Health Partnership+ (IHP+). Monitoring, evaluation and review of national health strategies: A country-led platform for information and accountability: https://www.uhc2030.org/fileadmin/uploads/ihp/Documents/Tools/M_E_Framework/M&E.framework.2011.pdf
[9] WHO. Guide for conducting an Expanded Programme on Immunization (EPI) Review. https://apps.who.int/iris/bitstream/handle/10665/259960/WHO-IVB-17.17-eng.pdf
[10] WHO. Handbook on the use, collection, and improvement of immunization data (June 2018 draft). https://www.dropbox.com/s/8ivdiu0g5xvnlbc/handbook.pdf?dl=
[11] WHO, UNICEF and U.S. Centers for Disease Control and Prevention. Public Health Data Triangulation for Immunization and Vaccine-Preventable Disease Surveillance Programmes: Framework (draft). 2019. https://www.learning.foundation/vpd-triangulation-draft

Table 1. Examples of existing triangulation use in immunization programmes by objective[7]

Objective — Example question	**Examples of use**
1. **External data consistency check**— How good is data quality?	• Comparisons of different denominator, coverage, or surveillance data sources (Fig 3) • Data Quality Review (DQR)
2. **Diagnostic to target programme interventions** — What areas are at risk?	• Prioritization based on programme performance monitoring • Risk assessment tools for polio, measles, neonatal tetanus (Fig 4) • Health Equity Assessment Toolkit (HEAT) • Bottleneck analysis
3. **Estimation of coverage, target populations, or disease burden** — What is the actual coverage?	• Subnational immunization coverage estimation (Fig 5) • WHO/UNICEF Estimates of National Immunization Coverage (WUENIC) • Population estimates from World Population Prospects
4. **Evaluation of effectiveness or impact** — How effective is the immunization programme?	• Assessments of programme effectiveness or impact of immunization activities (Fig 6) • Post-vaccine introduction impact assessments
5. **Holistic assessment of programme adequacy** — Is programme performance in/sufficient?	• Outbreak investigations or response assessments • Polio Certification, Measles Elimination Verification processes (Fig 7)

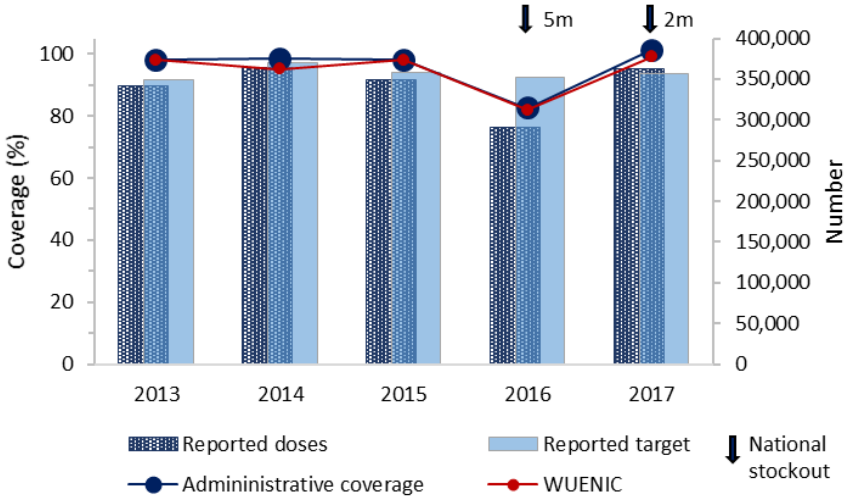


Fig. 3. External consistency check: Analysis of WHO/UNICEF Estimates of National Immunization Coverage (WUENIC) and reported administrative vaccine coverage, vaccine doses administered, targets, and national vaccine stockouts, County X, 2013-2017. A 5-month national stock-out was associated with lower coverage in 2016. Reported doses administered exceeded the reported target in 2017, indicating that programme targets may be underestimated. (Source: SAGE Data Working Group Report. Sept 2019)

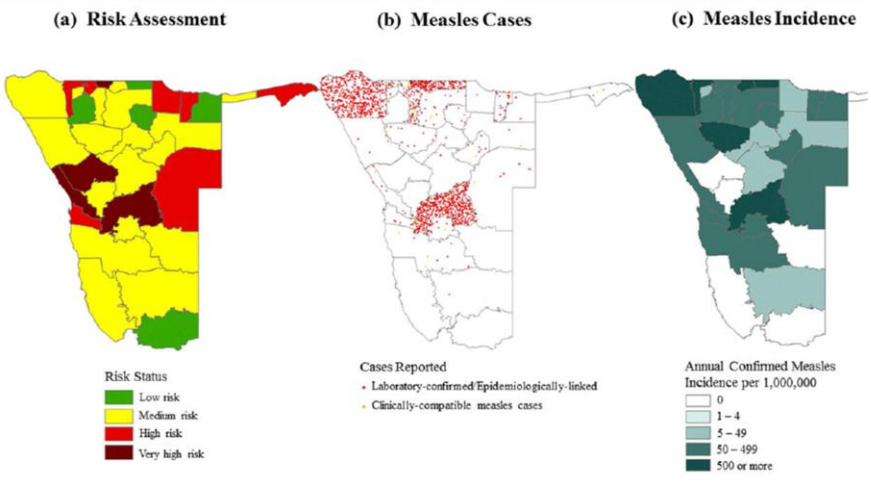


Fig. 4. Diagnostic to target programme interventions: Maps visualizing measles data, Namibia. (A) Measles risk assessment, 2006–2008, (B) measles surveillance cases, 2009, (C) measles incidence, 2009. Analysis showed areas assessed as very high risk using the measles risk assessment tool predicted measles outbreaks and disease risk, although this has not always been the experience in documented examples from other countries. (Source: Kriss et al. Risk Anal. 2017; 37(6): 1072-81).

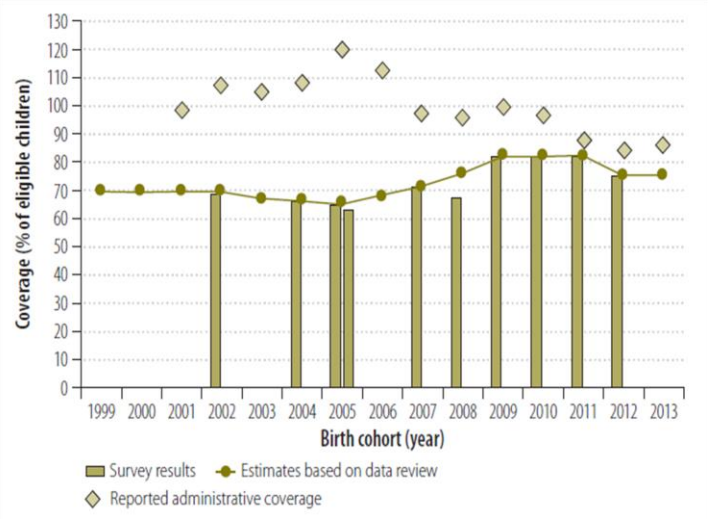


Fig. 5. Estimation of coverage: Third dose of diphtheria-tetanus-pertussis (DTP3) vaccine coverage in Chhattisgarh state, India from a subnational coverage estimation exercise with administrative coverage and survey data, 1999–2013. Administrative coverage was more consistent with estimated coverage and survey results after 2011. Source: Bhatnager et al. Bull WHO 2016;94:728-734.

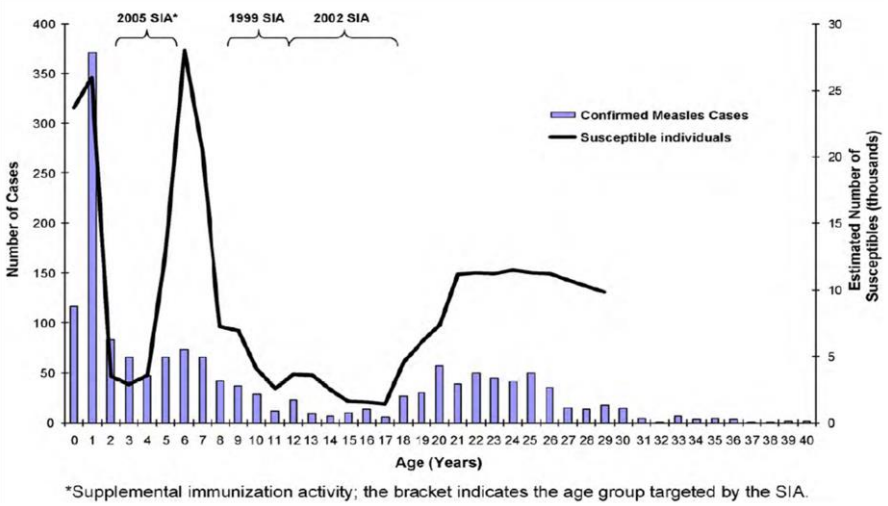


Fig. 6. Evaluation of effectiveness or impact: Measles cases and susceptibility by age based on vaccine coverage, effectiveness, and exposure to supplemental immunization activities (SIAs) — Tanzania, 2007. Confirmed measles cases generally occurred among age groups with greater susceptibility related to low vaccine coverage, or not being targeted by SIAs. Adults aged >30 years were considered protected by natural infection (Source: Goodson et al. Vaccine. 2010;28(37):5979-85).

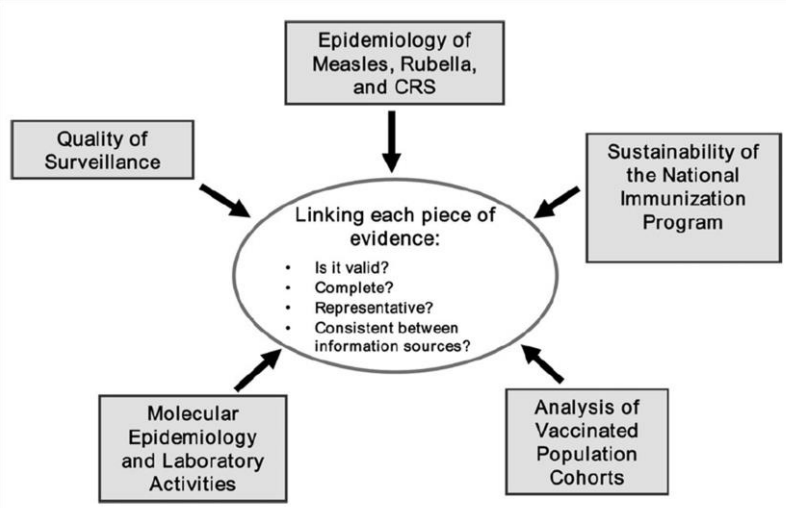


Fig. 7. Holistic assessment of programme adequacy: Schematic of the process of verifying Measles, Rubella, and Congenital Rubella Syndrome Elimination in the Region of the Americas. Various data are linked and evaluated regarding quality and consistency between sources to verify whether evidence is sufficient to verify interruption of endemic disease transmission. (Source: Castillo-Solorzano et al. J Infect Dis. 2011;204 Suppl 2:S683-9).

Case Study 1: Triangulation of Coverage and Vaccine Stock for Better Stock Management

In one country, a triangulation exercise was performed to better understand programme performance and data quality using administrative coverage and vaccine stock consumption data at subnational levels (i.e., regional and district vaccines stores and health facilities).

Key findings:

- The results indicated that the numbers of children reported as vaccinated were consistently higher than the quantities of vaccines issued by the national vaccine store to the regional vaccine stores.
- Data validation was not occurring consistently.
- A subsequent root cause analysis demonstrated that most health facilities lacked vaccine registries or were not completing them properly.

Action plan: The country decided to tackle those issues by strengthening partnerships to ensure printing and distribution of registers, tally sheets, and other primary data collection tools. To improve data validation, coaching and on-the-job training was planned for priority areas.

1.6. Benefits of triangulation

The potential benefits of data triangulation for EPI programmes are as follows:

»» Uses existing data and simple analysis skills, making it accessible and usually low cost;
»» Encourages collaboration across programme units and the potential for greater data sharing and access through high visibility of a shared data triangulation task;
»» Aids deeper understanding of data through synthesis with contextual information, framing within the epidemiologic and/or programme process, and consideration of data limitations;
»» Identifies areas for programme improvement, including data quality issues, that might not be apparent from use of individual data sources;
»» Improves confidence in conclusions and the quality of recommendations for planning and policy/strategy decision-making;
»» Strengthens the health system and promotes a "data-use culture" by building capacity for critical thinking, data analysis and use within an increasingly data-rich environment.

Examples of how triangulation results can be used by immunization programmes

»» Tracking trends/drivers of VPD transmission and progress towards elimination
»» Identifying areas with zero-dose and under-immunized children
»» Identifying reasons for low demand for immunization
»» Forecasting vaccine need at each level of supply chain
»» Monitoring and evaluating immunization programme performance
»» Prioritizing areas in need of supervision or targeted assistance
»» Developing immunization programme policy and strategy
»» Revising guidance and processes, including for data collection and management
»» Allocating resources and mobilizing political commitment (advocacy)
»» Informing and educating the public (media)
»» Guiding future research and evaluation

1.7. Limitations of triangulation

Every country and local setting is unique. Beyond the capacity for triangulation, many reasons exist for not effectively using data, from lack of data access to lack of personal motivation or a supportive culture to use data for programme improvement.[12] **Triangulation is not a magic solution** to these larger issues. Activities to increase uptake of triangulation may provide incremental changes that are helpful in moving towards a "data-use culture" (see Section 4.2).

A potential limitation of data triangulation is for the interpretation to converge at a single conclusion that is not accurate. This possibility can be minimized through use of data sources with independent collection methods (see Section 3.2). Other limitations of triangulation are included in Section 3.3.2.

Word of caution

Triangulation may highlight programme areas that are underperforming and issues that are potentially sensitive. While sharing of findings is encouraged, it is acceptable to keep some results private, or to share de-identified results for the sake of sharing lessons learned.

The most important thing is to optimize data use at each level to improve the immunization programme. Likewise, programme managers, technical partners and donor organizations should increase their openness to discovering weak points without fear of penalty, so that the data quality improves and the goal of reaching every child can be achieved.

2. Overview of Triangulation

2.1. Principles of Data Triangulation

Below are six guiding principles of using data triangulation for immunization and surveillance programmes (adapted from Rutherford *et al* 2010).[4] Of all of the principles, **inclusion of diverse data sources** (#3) sets triangulation apart among other analysis methods.

1. Objective-driven process. Questions related to key programme issues should drive the data triangulation process. The scope should be limited based on what questions can be answered and acted upon, given the available time and resources (see Section 3.1).

2. Use of existing data. Generally, data triangulation is conducted as a desk review using available data. Triangulation of existing sources could identify a need for more data collection or field validation as part of the next steps, but this piece is considered outside the scope of data triangulation guidance.

3. Inclusion of diverse data sources. Use of multiple, diverse datasets can help overcome the limitations of any one data source or data collection methodology and deepen understanding. Data including trends and showing a chain of events (Fig 2, e.g., vaccination coverage and disease incidence) may be particularly helpful. Explanatory studies and qualitative data may help provide contextual information and potential causes for the results (see Section 3.2).

4. Engaging a multidisciplinary team. Triangulation benefits from broader collaboration across different government units and other organizations with varied expertise and access to data sources. It is important to engage key stakeholders for formulation of questions, identification of data sources, data interpretation, and dissemination of results (see Section 2.3).

[12] Arenth B et al. Defining and Building a Data Use Culture. Goertz H, ed. Seattle: PATH; 2017. Available at: http://bidinitiative.org/wp-content/uploads/PATH_Building-Data-Use-Culture_R1.pdf

5. Simple analysis and interpretation of results. Triangulation should focus on simple analyses, data visualizations, and interpretations which integrate local context and knowledge. The interpretation of results should explain areas of agreement, disagreement and any limitations, as well as string the pieces of evidence together in a story (see Section 3.3).

6. Communicate results for improved decision-making. Decision-makers should be engaged from the beginning in any triangulation activities, so that they are invested and open to hearing the results. All triangulation should be used to inform programme management, improvement planning, and/or decision-making on programme policy and strategy.

2.2. Where to Use Triangulation

Use of data triangulation is relevant for most contexts and a variety of different purposes from routine monitoring to ad-hoc evaluation. In terms where it is most appropriate to conduct triangulation, the following are the suggested **minimal criteria***:* 1) existence of two or more data sources that address the topic of interest (usually related to the same geographic areas and/or time period), 2) capacity for data management and analysis, and 3) willingness to look deeper into the data and make decisions based on the results. A lack of any of these three criteria is a potential barrier to implementation.

Data triangulation can be implemented at multiple levels within the same country at the same time. The administrative level at which the exercise is conducted depends on the question being asked.

2.3. Who to Include in Triangulation

The team involved in the triangulation process will vary based on the level (national vs. district), and frequency of implementation (routine vs. ad-hoc). In general, the **minimal skills and job functions** possessed by a triangulation team include 1) data management, 2) data analysis, and 2) programme management (with decision-making authority, or with the ability to effectively disseminate to such a person). Depending on the task, including a range of skillsets[13] and a mix of staff from government at different administrative levels, partner organizations, public health fellowship programmes, and universities is advised.

One person could theoretically complete the triangulation process, if they had all the skillsets and job functions listed above. In many cases, it will be **important to engage decision-makers and those responsible for implementation from the beginning** of the triangulation exercise. These people are the primary audience for the results and should be involved in outlining issues/questions and developing a plan based on the results. As time allows, meeting with the team throughout the process allows for a better product with stronger conclusions.

At the **national level**, a triangulation exercise should include the EPI programme manager, logistician, data manager/biostatistician; other relevant staff from the EPI, surveillance, health information, and statistics units; National Immunization Technical Advisory Groups (NITAGs); and immunization partners working in or familiar with the country context. For routine analysis, the team required may be considerably smaller than for larger, less frequent evaluations.

At the **subnational level** (i.e., province or district), triangulation may be performed by the local biostatistician or data manager with input from the EPI, vaccine logistics, surveillance, and health information officers. Involvement of other relevant local staff (e.g., statistics bureau, civil society

[13] Epidemiology, surveillance, service delivery, logistics, training, communication, demography and statistics

organization) or assistance from national immunization or surveillance staff could improve the quality of the exercise.

2.4. When to do Triangulation

The triangulation process and principles can be applied in **day-to-day** monitoring and decision-making. Data triangulation can also be used for **less frequent** analyses to address programme questions that might take many months to investigate. Formal data triangulation workshops may be conducted initially, but **integration of triangulation into regular programme processes, tools, and activities** is recommended for greater long-term sustainability (see sections 2.6 and 2.7). Triangulation results are also more likely to be used if conducted in the context of routine planning, monitoring, and evaluation cycles.

2.5. Introduction to the Triangulation Process

A simple **4-step triangulation approach** is the basis of the Subnational Guidance and is relevant for routine monitoring (Fig 8). Triangulation should always start by identifying a programme issue and framing as an actionable question. Then, existing data sources are identified and summarized with relevant local context. The process ends with developing an action plan, where triangulation results are used for planning and decision-making.

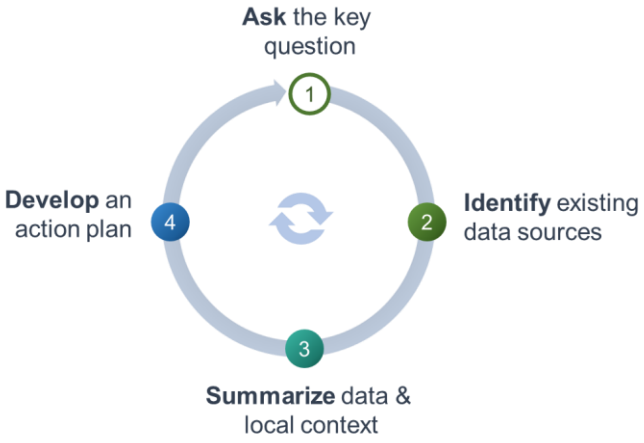


Fig. 8. The fundamental 4-step EPI triangulation process, starting with a key question and ending with informing action. The process is useful for routine monitoring and can be repeated in an iterative fashion.

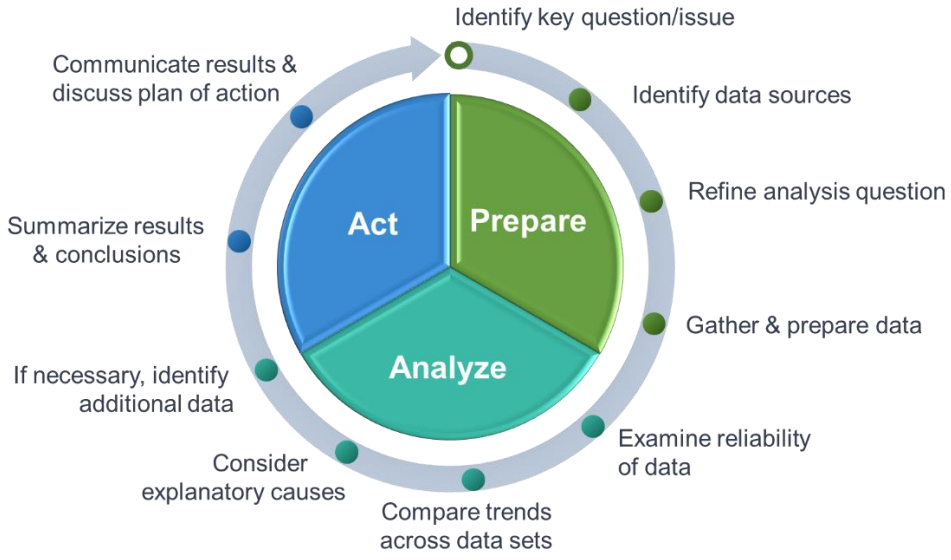


Fig. 9. The in-depth 10-Step EPI triangulation process. This approach has three stages and is useful for larger analyses as part of periodic evaluations. Adapted from the 12-Step Process for HIV/AIDS Programmes.

For completing more substantial data triangulation analyses, the triangulation process has been further detailed into **10 steps within three phases**: Plan, Analyze, and Act. While each step is important to the triangulation process, not all steps take a lot of time or effort. Similar to the 4-step process, the 10-step process starts with identifying the key question or issue and ends with communicating results and discussing a plan of action (Fig 9). The 10-step process is flexible to accommodate a variety of questions relevant for immunization and surveillance programmes (see Appendix A).

Triangulation need not be lengthy, particularly if the analysis builds on previous work. If preparing a triangulation analysis for the first time, there may be initial time investment to prepare the data sources and analysis template. Once an initial analysis has been done, updating can be quick, easy and yield good results. Analysis could be further automated for routine use.

Triangulation is an **iterative process**. The results from any given step can help inform previous steps, and, as new information becomes available, previous steps may need to be revisited. For example, you may need to revise your question if it cannot be answered using existing data. Finally, the results of one exercise may result in a new question worthy of further exploration or the need to collect additional data to confirm possible explanations generated during triangulation.

2.6. Triangulation Use in Routine Monitoring

Individual use of triangulation using the 4-step approach for routine monitoring and decision-making work need not be an involved process. For example, triangulation could be incorporated into the **routine analyses** done as part of monthly feedback on reported data and EPI data review meetings (e.g., monthly, quarterly). However, attempting to incorporate triangulation more systematically into routine data use in programme could require more time and effort.

Examples of **routine processes and tools** where triangulation can be integrated include microplanning, vaccine forecasting, supportive supervision, and data quality validation. If triangulation was not included in the original design, the relevant task may be to optimize routine monitoring tools and processes to include triangulation. In this case, starting with an initial Systems Assessment[14] or some other evaluation (e.g., EPI/VPD Surveillance Review[15]) would be helpful to allow discovery of what activities would benefit from inclusion of triangulation.

In the case of routine monitoring, information systems or other tools may include automated analyses with set data sources to address relevant questions and save time for the end-user (e.g., which areas have gaps in performance or data quality requiring follow-up?). Incorporating triangulation into **dashboards** within systems that integrate various types of data would be ideal for assessing ongoing trends. Creating system interoperability or adding reference datasets (e.g., geospatial, population data, coverage surveys) to facilitate triangulation is also relevant.

Finally, dashboards and tools cannot perform all the triangulation work for the end-user. **Training in data triangulation and critical thinking skills** may be required to support staff in processing data into usable information (e.g., interpretation and communication) (see Section 4.1).

[14] WHO. Handbook on the use, collection, and improvement of immunization data (June 2018 draft). https://www.dropbox.com/s/8ivdiu0g5xvnlbc/handbook.pdf?dl=

[15] WHO. A guide for conducting an Expanded Programme on Immunization (EPI) Review (2018). https://www.who.int/immunization/documents/WHO_IVB_17.17/en/

Some qualities of a critical thinker:

»» Identifies key issues and related questions that are answerable and actionable;
»» Gathers and assesses relevant information, integrating with contextual information and local knowledge to effectively interpret results;
»» Considers multiple viewpoints, recognizing and assessing their assumptions, implications, and practical consequences; and
»» Comes to well-reasoned conclusions and solutions, considering data limitations and priorities based on resource availability;
»» Communicates effectively with others in figuring out solutions to complex problems.[16]

2.7. Triangulation Use in Periodic Evaluations

Performing any kind of substantive analysis takes time and effort. To optimize efforts, triangulation could be included in existing **regular periodic activities** where analysis is already performed, such as annual desk reviews of immunization data, and annual meetings of the NITAG, and National Committees for certifying polio eradication or verifying measles and rubella elimination. Less frequent opportunities (e.g., every 5 years) include periodic in-depth assessment of routine immunization data, development of comprehensive multi-year strategic plans (cMYP), immunization data quality assessments, and EPI or VPD Surveillance Reviews. Other ad-hoc opportunities include donor funding applications and outbreak investigations.

Gavi's Joint Appraisal Analysis Guidance (2020) was developed in collaboration with the current guidance and includes relevant triangulation guidance and examples. This guidance can be used to prepare for Joint Appraisals or may be helpful for data desk reviews, more generally. Available at: https://www.gavi.org/our-support/guidelines/report-and-renew

For **larger ad-hoc evaluations**, a Data Triangulation Team/Task Force could be formed to raise the profile of the activity and allow greater coordination (Case Study 2). Workshops can aid high-level engagement from diverse stakeholders. Performing a Systems Assessment[17] may be relevant to explore how triangulation could be used to optimize existing processes and to examine underlying issues in-depth.

For larger projects, identifying a person who can dedicate time to data management and data analysis is important. In addition, logistical support for organizing meetings, and assisting with obtaining the data is needed. Special consultants could be considered to handle the demands of gathering and managing the data, as well as analysis tasks, in close consultation with programme staff. An example of a timeline for a conducting a larger triangulation exercise in a country is below.

[16] Paul R, Elder L. The miniature guide to critical thinking: concepts and tools. Dillon Beach, CA; 2006, Foundation for Critical Thinking.
[17] WHO. Handbook on the use, collection, and improvement of immunization data (June 2018 draft). https://www.dropbox.com/s/8ivdiu0g5xvnlbc/handbook.pdf?dl=

Case study 2: Composition and Leadership of Country Triangulation Teams

In one country, a Country Triangulation Team was comprised of government immunization, health information, and statistics staff, as well as immunization partners. The National Immunization Programme (NIP) was suffering significant human resource shortages, so the triangulation analyses were led by the Data Team of the WHO-Country Office, with meetings held periodically with the rest of the Triangulation Team. The WHO-Country Office viewed the exercise as an opportunity to build the analytic skills of their Data Team.

In another country, the NIP chose to lead the exercise. Data managers were motivated to learn new analytic skills for data use. A focal point was appointed and data triangulation working groups were formed, including government surveillance and health information staff, as well as partners. Overall, the triangulation exercise took longer time to complete than the first country because of the other competing work of the NIP.

Despite the additional work, both country teams conducted the work themselves without an external contractor to promote internal capacity building opportunities for local staff and greatly appreciated close mentorship and technical support from the US CDC.

Example of a Timeline for Larger-Scale Triangulation Exercise[18]

- Initial stakeholder meetings (1 day to 1 week): Stakeholders meet to identify and share the preliminary data available, decide on the key question(s), constitute a triangulation team, and begin inventorying relevant data sources. A systems assessment could be added, as relevant.
- Data preparation (weeks to months, depending on scale of exercise): Existing data are collected and collated, and data cleaning and initial analysis conducted.
- Data analysis (simultaneous with data preparation): Data are analyzed and interpreted.
- Training workshop (1–2 days): Using data captured in-country, a triangulation training workshop is conducted for epidemiologists and data analysts. The training workshop includes instruction on triangulation methods, refining and finalizing analyses to answer question(s), developing a summary of findings and tools and strategies to support on-the-job application.
- Final stakeholder meeting (1–2 days): Immediately following the training workshop, a meeting with stakeholders is held to present the key triangulation findings and discuss next steps.
- Final country triangulation analysis report (2–4 weeks): Produce a country analysis report to be delivered to key stakeholders.

[18] World Health Organization (WHO). HIV triangulation resource guide: synthesis of results from multiple data sources for evaluation and decision-making. Geneva: WHO; 2009. https://globalhealthsciences.ucsf.edu/sites/globalhealthsciences.ucsf.edu/files/pub/gsi-tri-oms-hiv-triangulation-guide.pdf

3. Key Issues in Triangulation

Several central issues for triangulation are discussed in this chapter: 1) how to ask a key question, 2) how to choose data sources, 3) how to summarize data, and 4) how to use data to plan for action. Further detailed guidance and practical considerations for performing the 10-step process is provided in Appendix A.

3.1. How to Ask a Key Question

Triangulation should always start with a **key programme question(s), which can be answered and acted upon**. Another way to orient is to ask what is the issue that you are trying to solve with triangulation, or how you **hope to use the results** for planning and decision-making at the end.

Developing question(s) is a **critical-thinking activity**, in of itself. Coming up with a key question requires reflecting on existing knowledge of local context and asking what other information is needed to make the best decision on the way forward. Individual experience and capacity may vary, so it is relevant to engage staff from a variety of programs and levels in formulating key questions (see Section 2.3).

Below are some suggested approaches to start to identify questions:

- Brainstorming questions.
- Reviewing examples of questions and seeing which feel most relevant for your context.
- Having a discussion of important issues, where a skilled facilitator notes specific topics of debate that need further information.
- Reframing hypotheses, or explanations made based on limited evidence, in the form of a question.

For example:

- "You raised that you think denominator issues are worse in urban areas. That sounds like a good hypothesis. What do you think of examining differences in target populations and growth rates for urban and rural areas and see what we find?"
- "You mentioned observing that stock data are not reliably filled in the register and reported. Are you interested to see how big of a problem this is across different sub-districts?"

Table 2. Criteria for data triangulation questions[19]

Criteria	Description
Important	• Is the question important and timely based on local priorities?
Answerable	• Are data available to address question? • Has adequate time elapsed for the process to lead to measurable outcome?
Actionable	• Will the answer lead to initiation of public health action? • Will identified issues be able to be changed through interventions?
Appropriate	• Is the question better addressed research methods or analysis of a single data set?
Feasible	• Are sufficient time and resources available for completion?

It is fine to start with many questions, and then narrow questions down based on the following **defined criteria:** important, answerable, actionable, appropriate, and feasible (Table 2). For "actionable," the resulting action may be at your administrative level, the level above or below, or

[19] Rutherford et al. Public health triangulation: approach and application to synthesizing data to understand national and local HIV epidemics. BMC Public Health. 2010;10:447. https://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-10-447

multiple levels. Using a question(s) that meets these criteria ensures that the exercise is worth the effort and ensures that the exercise is time-limited and leads to actionable information. If questions do not meet these criteria, it is recommended to revise the question(s) to meet these criteria.

It is especially important is to engage **decision-makers and other key stakeholders from the beginning** to develop the question as they will be the audience for the findings in the end and also be involved in implementing the resulting actions. If decision-makers are involved in identifying the important question, they should be more invested in the results of the triangulation exercise and may also be more open to the importance of addressing any programme performance or data quality gaps identified in the process.

Case Study 3: Triangulation to assess denominators, improve programme monitoring, and identify immunity gaps, Country X

Country X organized a Triangulation Team to conduct an exercise at the national and sub-national level, with support from the World Health Organization and U.S. Centers for Disease Control (US-CDC). The Team observed that despite success in implementing a Health Information System including coverage, vaccine stock, and case-based surveillance, as well as conducting subnational coverage surveys, capacity for data use was lagging at various levels of the immunization workforce.

The Team highlighted programme target (denominator) inaccuracy as their biggest issue, followed by immunization data quality (numerator). As a result, vaccination coverage >100% was being reported in most districts, while confirmed measles cases were still being detected, often with no history of vaccination. For this reason, the Team chose to focus on three topics and developed relevant triangulation questions for their context:

1) Immunization programme targets (denominator): *How do national and subnational estimates of infant population targets and growth rates from different sources compare?*
2) Immunization programme monitoring: *What are the vaccination coverage and stock data quality issues in districts, and which analyses are most relevant for routine monitoring?*
3) Measles and rubella immunity gaps: *Are there age cohorts, geographic areas, and subpopulations with suboptimal population immunity?*

The final triangulation analyses produced helpful insights around the extent of denominator issues (underlying causes were revealed through follow-up field investigations), how coverage and vaccine stock data could be used to assess data quality issues, and how surveillance and other data could be used to identify immunity gaps at the operational level.

Action: Based on these findings, the Team revised microplanning guidance; developed guidance on minimal immunization dashboard elements; and flagged areas with lower immunity for support in planning /monitoring during an upcoming vaccination campaign. Workshops and trainings of subnational staff on data triangulation were conducted and well-received.

3.2. How to Choose Data Sources

For triangulation, use of **multiple, diverse data sets** is recommended for a more complete understanding of the programme issue and overcoming the limitations associated with any one data source or data collection methodology. Examples of existing data sources include administrative coverage, coverage survey, vaccine supply, programme management, disease incidence (surveillance), population data, as well as modeled data and data from special studies (e.g., publications, evaluation reports, student theses).

Identifying existing data sources is challenging because it involves discovering all data sources, including those not in routine use. **Talking to colleagues** inside and outside the programme, within the government and among partners, is helpful to discover other data sources which could be helpful. Including colleagues from relevant units and organizations from the beginning can help facilitate **data access**. Time and effort can be required to compile data in usable format. **Creating an inventory** of these data sources and storing all the data in a **centralized archive** that is well-organized can be invaluable and aid more regular future use.

When choosing data sources, it is important to consider the underlying context and how the data relate to one another within a monitoring framework (Fig 2). **Data that include trends** and are related in a chain of events (e.g., vaccination coverage and disease incidence) may be particularly helpful for triangulation. Inclusion of **local contextual information and qualitative data** (e.g., EPI/VPD surveillance reviews, missed opportunities, hesitancy studies) can helpful for interpreting results (Table 3). Table 4 summarizes different types of data and indicators that could be used for triangulation from immunization and VPD surveillance, as well as other programmes (e.g., statistics, family planning, antenatal care).

Table 3. Comparison of qualitative and quantitative data [20]

Qualitative	Quantitative
• Use observation and words as data • Goal is to explore and discover • Ask "how" and "why"? • Collected through interviews and observation • Case-oriented (small sample size) • Not representative or generalizable	• Use numerical data • Goal is to verify or prove • Ask "how many"? • Collected through programme reports and surveys • Population-oriented (large sample size) • Have generalizability as a goal

Data sources that are **independent** in terms of their collection method are generally more helpful for assessing and addressing the limitations of individual data sources. For example, if there are challenges with poor data entry or private providers not submitting reports, this problem will exist in both the coverage and vaccine stock reports. Each data source has **strengths and limitations,** which need to be weighed carefully during triangulation (Appendix C).

After choosing data sources, you need to **determine the different measures** that you will use and what will provide the clearest interpretation for your audience. Will you use the raw data as they are reported or will you calculate indicators (e.g., % with defined numerators and denominators)? Below are suggestions on how to use your data.

»» For disease incidence, reporting cases as the number of cases occurring within a population and specified time period (e.g., 10 per 100,000 or million annual population) is a considered a more accurate reflection of risk than only reporting cases during a defined time period.

»» Absolute risk or change may be easier to understand and less likely to mislead than relative numbers (e.g., percentages or fold-differences). For example, an increase from 4 to 5 cases is less of less public health significance than an increase from 400 to 500, but both are 25% increases.

»» If you are trying to compare two measures that should be about equal (e.g., doses administered and vials used), displaying as a percent or fold difference where equality equals one may be easier.

[20] World Health Organization (WHO). HIV triangulation resource guide: synthesis of results from multiple data sources for evaluation and decision-making. Geneva: WHO; 2009. https://globalhealthsciences.ucsf.edu/sites/globalhealthsciences.ucsf.edu/files/pub/gsi-tri-oms-hiv-triangulation-guide.pdf

Table 4. Examples of possible data sources and measures for triangulation

Category	Examples of specific data sources	Examples of specific measures
Census	• National census • National census projections • Special population censuses	• No. live births/surviving infants • Birth/infant growth rate • Infant mortality rates • Internal & external migration rates
Registries	• Civil Registration & Vital Statistics (CRVS) • Birth registration • Electronic immunization registries (EIR) • Sample registration systems	• No. live births/surviving infants • Infant mortality rates • No. vaccine doses administered
Surveys	• Demographic Health Surveys (DHS) • Multiple Indicator Surveys (MICS) • Expanded Programme on Immunization (EPI) surveys • Post-campaign coverage surveys • Seroprevalence surveys • Vital statistics surveys • Knowledge, Attitudes, Practices (KAP) surveys	• Vaccination coverage (%) • Coverage inequity ratio • Reasons for non-vaccination • Seroprevalence (%) • Birth/infant growth rate • Infant mortality rates • Internal/external migration rates • Knowledge about vaccines
Surveillance	• Case-based disease surveillance • Aggregate disease surveillance • Laboratory surveillance • Environmental surveillance • Adverse Events Following Immunization (AEFI) • Health and demographic surveillance sites	• No. suspected/confirmed cases • Disease incidence rate • Age/vaccination status of cases • Hospitalization/case fatality rate • Performance indicators • No. AEFIs
Programme data	• Vaccine administration reports • Vaccine stock management reports • Cold chain/temperature monitoring reports • Immunization microplan • Programme head counts • Supervision reports • Human resource reports • Planning/commodity data from other programs (family planning, antenatal care)	• Vaccination coverage (%) • No. vaccine doses administered • No. vials used/shipped • Wastage (%) • No. of temperature alarms • Vaccination sessions conducted (%) • No. vaccinators/health workers • No. live births/surviving infants • No. pregnant women • Births with skilled attendants (%) • Antenatal care visits (%)
Modeled data	• WHO/UNICEF Estimates of National Immunization Coverage (WUENIC) • World Population Projections (WPP) • Global Burden of Disease (GBD) estimates • Geospatial modeled estimates	• Est. vaccination coverage (%) • Est. no. live births/surviving infants • Est. no. disease cases • Est. no. disease-related deaths
Special studies	• Missed opportunities for vaccination • Vaccine effectiveness studies • Demand/hesitancy studies, e.g., focus groups • Healthcare provider studies • Reviews of medical records/insurance data	• Vaccine effectiveness (%) • Case fatality ratio • Awareness/confidence in vaccination • Reasons for non-vaccination • Cultural beliefs related to vaccines
Programme reports	• EPI/VPD Surveillance Reviews • Data Quality Assessments • Rapid Coverage Assessment • Campaign technical reports • Outbreak investigation reports • Annual reports with analyses	• Children vaccinated in field (%) • Performance indicators • Awareness of vaccination • Reasons for non-vaccination • Data accuracy ratio • Qualitative observations
Contextual information	• Immunization schedule • History of campaigns • History of surveillance/surveys • Any changes in reporting definitions • Major events (disasters, health sector issues) • Media reports (AEFIs, rumors)	• Year of vaccine introduction • Vaccine formulation by year • Year of campaigns • Time period for major events • Qualitative observations

Disease outbreaks reveals programme performance gaps

Measles outbreaks are considered sentinel events because the disease is very infectious, and outbreaks can occur in places not achieving high coverage (93%-95%) with two doses of vaccine. Outbreaks of rubella, diphtheria, and poliovirus, including vaccine derived poliovirus (VPDVs), occur at much lower coverage levels (less than 80%-85%).

Many countries have the experience of detecting frequent outbreaks of different VPDs in the same high-risk group that is missed by routine immunization. Conducting enhanced surveillance after an outbreak of one VPD may even result in finding other VPDs that were previously undetected. In this way, surveillance can help find gaps in immunization coverage.

For more information, see the Guidance Annexes on Immunity Gaps and Programme Monitoring.

Case Study 4: Triangulation of Coverage and Contextual Factors to Identify Barriers to Vaccination

In one country, monitoring of routine administrative vaccine coverage data identified some provinces with low coverage of hepatitis B birth-dose (HepB-BD). A triangulation exercise was performed to understand the barriers to vaccination using coverage data, available media reports, and data from a rapid assessment of caregivers and healthcare providers to identify potential barriers to vaccination.

Key findings:

• A series of fatal and non-fatal adverse events following immunization (AEFIs) related to HepB-BD (and later linked to human error) were widely reported in the media in the preceding year.

• Healthcare provider confidence to vaccinate was negatively influenced by the media reports.

• Caregivers, who were initially worried about AEFI, indicated that their minds were changed as a result of conversations with providers highlighting the benefits and safety of HepB-BD.

Action plan: The country decided to develop targeted trainings for healthcare providers on AEFIs and strengthen post-vaccination monitoring to build healthcare provider knowledge and confidence.

ANALYSIS is breaking down the issue of interest in order to understand each individual part.

SYNTHESIS is combining many parts into a whole, in order to understand similarities, differences, and connections between each individual part.

3.3. How to Summarize Data

In this guide, we will explain **two ways to summarize data** during triangulation. The first is to assemble different data together in one graph or chart (Figs 3, 5, and 6). The second is to make several graphs and stitch the different findings together with a narrative thread, or story (Figs 4 and 7). In general, both ways of triangulation require comparison of the data across the **same geographic areas (e.g., sub-districts) and time periods**. Critical thinking is required in both cases to make sense of the data and convey usable information to your audience.

3.3.1. Analysis

Analysis as part of the triangulation process includes 1) **assessing data quality**, or the data completeness and internal consistency, as well as 2) **assessing trends across data sources**. Often, we are concerned with exploring disease and immunization programme data by **person, place and time**. Incorporating contextual information and local knowledge (e.g., year of vaccine introduction or campaign) will improve the quality of the analysis.

A best practice is to develop a detailed **analysis plan** (e.g., list of outputs, variables for comparisons, dummy tables, etc.) and to stay true to this plan as much as possible during the analysis. A challenge with implementing triangulation is that analysts can easily focus on results from data sources that support a preferred conclusion (whether done consciously or not). Following an analysis plan and making sense of all of the results helps avoid this issue. See Table 5 for other best practices.

In general, only **simple analyses and data visualization** are needed. Most graphical analysis can be performed in Microsoft Excel. If you are looking to improve your Excel skills, many tutorials, videos, discussion forums can be found by searching online. Other resources are listed in Appendix B.

Table 5. The dos and don'ts of performing data triangulation

DO	DON'T
Focus the analysis based on the key question identified.	Perform an unfocused analysis of everything imaginable.
Explore patterns and associations through descriptive and graphical methods.	Over-interpret small effects, even though they may be statistically significant ("data dredging").
Be open minded and consider alternative explanations.	Come to the process with preconceived answers and solutions.
Be honest about data limitations and consider performing sensitivity analyses to explore the impact of uncertainty, e.g., missing data.	Fail to document to limitations of source data.
Embrace uncertainty and enable your audience to view the results through a clear lens/full picture.	Discard results that do not fit your hypothesis.

3.3.2. Interpretation

Triangulation is not just a mechanical analysis activity, but also a **critical synthesis** activity. Looking at trends in the data by geographic area and time period helps reveal **areas of agreement or disagreement**, based on expectations. A critical view should be taken of data that is zero or missing, because of the challenges in making a reliable interpretation of this information. Areas needing further investigation can be flagged.

Interpretation should describe the observed relationship among data sources, or **how the data fit together**, as well as the potential limitations of each data source is key. **Be honest about data limitations**, e.g., missing data or errors (Appendix C). Considerations for interpreting comparisons of different data are summarized in Table 6. Examples are included in Figs 10 and 11.

Table 6. Examples of considerations for interpreting comparisons of different data

Comparison	Expected relationship/trends	Considerations for interpretation
Administrative coverage & survey coverage	Approximately equal	• Quality of reported data • Population movement • Role of private sector • Robustness of survey methods
Doses administered & vials used/shipped	Same direction, differ by a factor	• Vaccine presentation • Wasted/sacrificed doses • Buffer stock practices • Informal exchange networks
Vaccination coverage & cases of disease	Opposite direction, e.g., as coverage increases, incidence decreases	• Programme history, including vaccine introduction & supplementary immunization • Disease epidemiology (e.g., age of cases, herd immunity threshold) • Surveillance performance
Vaccination coverage & seroprevalence	Same direction, differ by a factor	• Vaccine effectiveness • Laboratory & survey methods • Quality of reported data
Vaccination coverage & service delivery	Same direction	• Quality of reported data • Impact of programme deficiencies

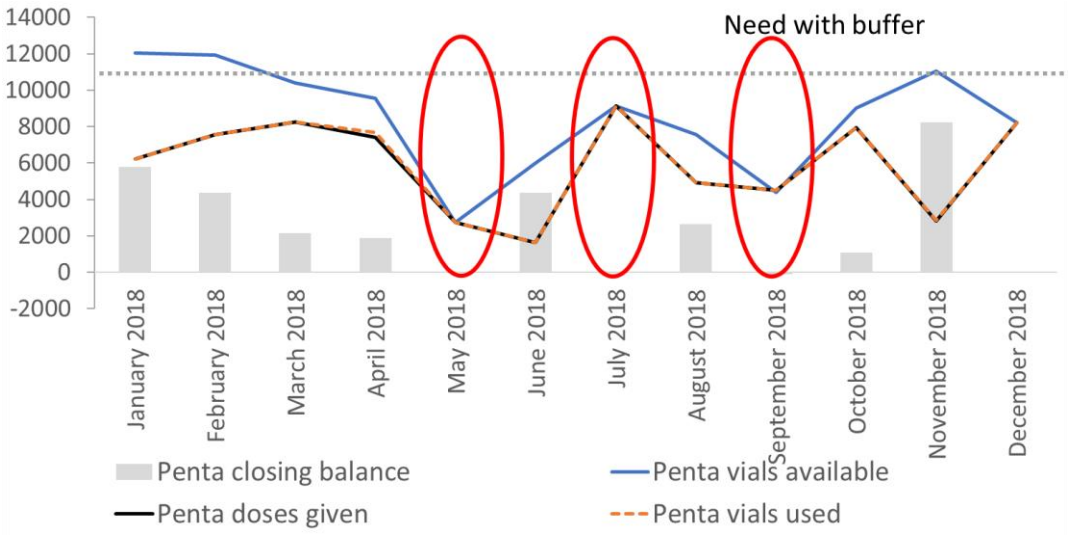


Fig 10. Comparison of total Pentavalent (Penta) doses administered vs. one-dose vials used (stock), vials available, and closing balance in a select sub-district, 2018. Good data agreement is observed between Penta doses given and vials used. There is some evidence that unreliable vaccine stock is affecting Penta coverage, e.g., months where all vials available are used resulting in zero closing balance (red circles).

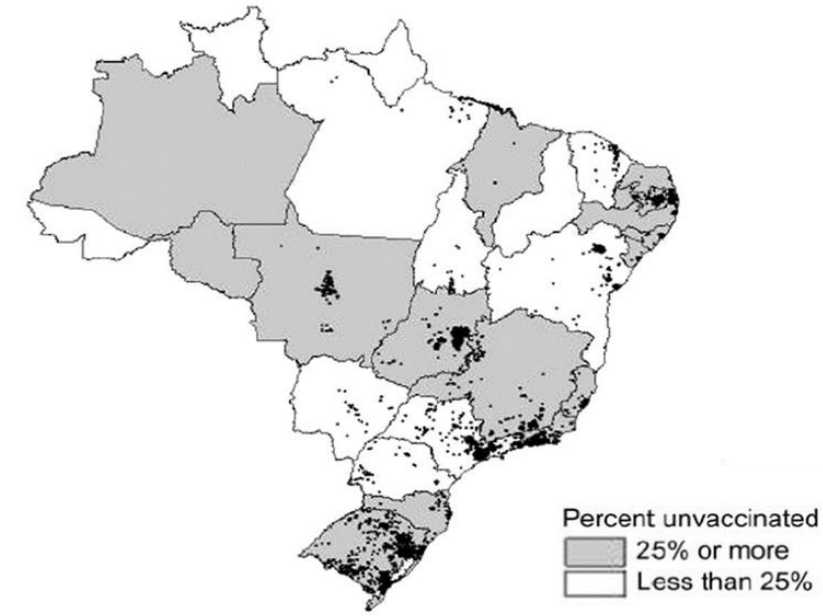


Fig 11. Map comparing percent unvaccinated vs. cases of disease reported through surveillance, Brazil, 2007. Each dot = 1 rubella case (n=8,751 cases). In general, more rubella cases were reported in states where 25% or more of the population 2–40 years of age had not been vaccinated against rubella, according to analysis of vaccination opportunities by cohort.[21]

It is usually helpful to **brainstorm multiple hypotheses** to explain the patterns observed in the data. It may be necessary to incorporate other data or go to the field and perform a root cause analysis to understand the true explanation. Incorporating contextual information and local knowledge is key to making sense of the data. The point of triangulation is to turn data into reliable information for decision-making.

Acknowledging limitations

Examples of the limitations of individual data sources are listed in Appendix C. General limitations of data triangulation, and mixed methods evaluations more broadly, can include the following:[22, 23]

- The quality, amount (i.e., sample size), and *independence* (different collection methods) of the original data should be considered, as the potential exists for interpretation of data to converge at a single conclusion that is not accurate.
- Without focusing on a key question, analysis of large datasets can lead to "data dredging," e.g., choosing findings that support your favorite hypothesis or over-emphasizing the importance of small differences that are statistically significant (p-value <0.05). This can be avoided by focusing on a key question and sticking to an analysis plan, which explores the patterns and differences of programmatic relevance through descriptive and graphical methods (Table 5).

[21] Segatto et al. Historical analysis of birth cohorts not vaccinated against rubella prior to national rubella vaccination campaign, Brazil. J Infect Dis. 2011 Sep 1;204 Suppl 2:S608-15. Available at: https://academic.oup.com/jid/article/204/suppl_2/S608/867099

[22] Rutherford et al. BMC Public Health. 2010;10:447.

[23] UNAIDS. An Introduction to Triangulation. Geneva: UNAIDS; 2010.

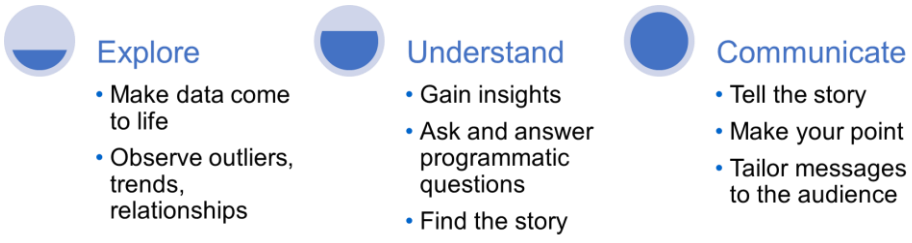
»» The potential exists to draw incorrect conclusions about individual risk factors based on analyses performed at the population level (ecological fallacy). Because triangulation examines consistency across data sources, the risk may be reduced compared to analyses of single datasets.

»» Qualitative data (e.g., EPI/VPD surveillance review, hesitancy studies) have the potential to be used inappropriately, i.e., through attempts to interpret quantitatively.

»» Finally, analyses have the potential to be unreproducible unless underlying data limitations are carefully considered, and the temptation to selectively ignore data not fitting a favored hypothesis is resisted (Table 5).

How Does Triangulation Relate to Data Visualization?

Many triangulation examples rely on effective data visualization for their impact. For this reason, data triangulation is often equated with data visualization. While the two are different, applying key data visualization principles will help improve your triangulation. A number of resources exist online, including the WHO handbook on *Effective Communication of Immunization Data*.[24,24] **When and why we use data visualization** is illustrated below.



3.3.3. Data visualization

Data visualization is the graphical representation of information and data. A first point is to **choose a graph** that best highlights the main finding you want to show in your data. Various "chart chooser" tools exist online and may be helpful for deciding on the best graph for the purpose and number of data points (Fig 12 and Appendix B).[25] **Try different options** to compare the clarity of the results for the message you want to tell. Curiosity-driven exploration is a part of the triangulation process. Examples of graph types and best uses are below:

Bar charts are good for simple comparisons because the eye can most easily discern the differences. **Barbell graphs** are another option, but take some time tinkering in Excel (Fig 13).

Line graphs are helpful to show trends over time and/or include more data points.

[24] Tableau. Data visualization beginner's guide: a definition, examples, and learning resources. https://www.tableau.com/learn/articles/data-visualization

[25] WHO European Regional Office. Effective communication of immunization data (2019). http://www.euro.who.int/en/health-topics/disease-prevention/vaccines-and-immunization/publications/2019/effective-communication-of-immunization-data-2019

Scatter plots are good for showing the relationship between two datasets, even across many data points. Bubble graphs are a variation of the scatter plot where the proportional size of the bubble shows a third variable.

Mapping can be a powerful tool for looking at geographic distribution of data (dot density map) or geographic trends in indicator values (choropleth map) (Fig 14).

Stacked column charts show the composition of a group, e.g., vaccination status of confirmed measles cases. For a stacked column, displaying absolute numbers is usually more helpful than proportions summing to 100%.

Histograms show distribution (or variation) of many data points for an indicator (e.g., date of onset). Epi-curves are a special type of histogram for the date of illness onset among cases associated with an outbreak.[26] Box-and-whisker plots are another way to display distributions (Fig 12).

Combination graphs (combo graphs) are helpful for combining multiple types of data in the same graph. Age-period-cohort analysis is a special combination graph for understanding differences in the risk of disease based on birth year (Fig 15). Variations in disease risk can be related to the effects of aging, external events (e.g., war, economic crisis, changes in case definitions or data collection method), or the unique exposure of a group of individuals (cohort) as they move across time (e.g., vaccination coverage, exposure to SIAs).

Table 7 summarize some best data visualization practices related to the principles of **simplicity, clarity and accuracy**.[12] To aid interpretation, it is recommended to **annotate charts and graphs** with important context. You can use circles, arrows, lines and text labels with key information, as needed. For example, adding an arrow for when a vaccine was introduced, what age cohorts were targeted by SIAs, or a line with the expected benchmark for an indicator can make a graph much more easily interpretable (Figs 10 and 13). Adding a **descriptive title** or 1–2 bullets with **key points of interpretation** can not only help your audience, but also help you track how your story is fitting together. Critical thinking and creativity are crucial to the success of the triangulation process.

[26]CDC. Quick Learn Lesson: Create an Epi Curve. https://www.cdc.gov/training/quicklearns/createepi/

Fig. 12. Chart Chooser based on the purpose and number of variables & data points. (Source: WHO-European Regional Office. Effective Communication of Immunization Data[20])

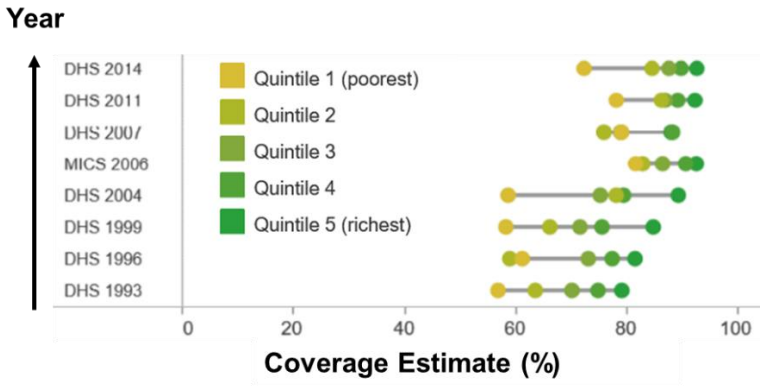


Fig. 13. Barbell chart showing vaccination coverage estimates by wealth quintile from different surveys. Despite increasing trends over time, coverage is generally lower in the poorer quintiles and higher in the richer quintiles (Source: WHO Health Equity Monitor, https://www.who.int/gho/health_equity/en/)

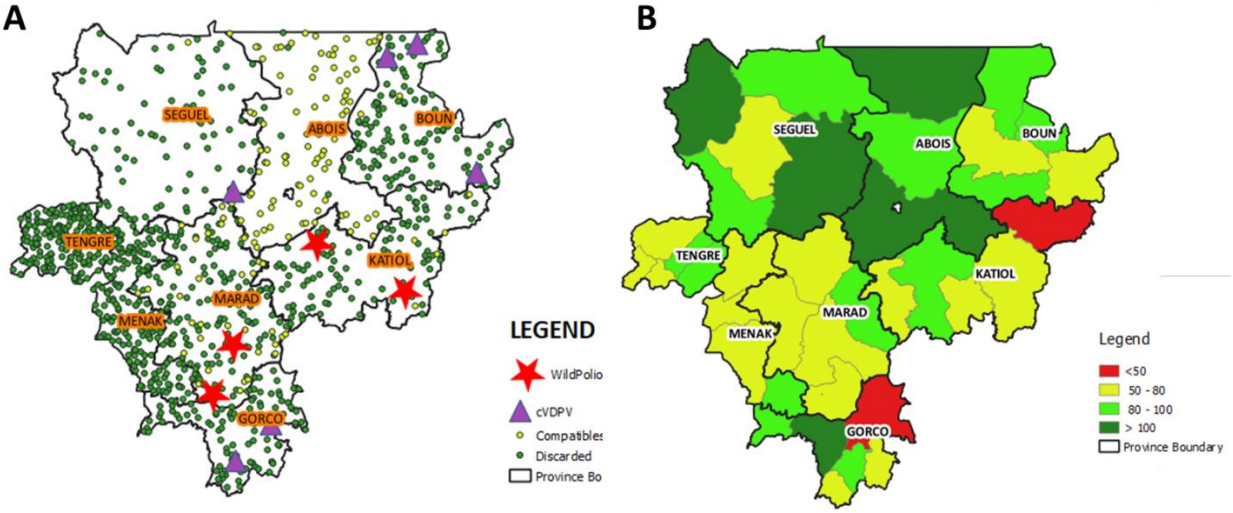


Fig. 14. Comparing a dot map of final classification of acute flaccid paralysis (AFP) cases (A) and third dose coverage with oral poliovirus vaccine (OPV3) by district, 2016 (B). Wild poliovirus cases (stars) and circulating vaccine-derived poliovirus (cVDPV) cases (triangles) were detected in areas reporting varying levels of coverage, while districts reporting coverage <50% reported confirmed no polio cases. This result raises questions about the quality of subnational vaccination coverage and surveillance data. A high number of compatible cases was reported in one state with higher coverage (Abios), raising concerns about surveillance data quality there.

Table 7. Best practices for data visualization[27]

Principle	Best practices
Simplicity	• Choose the graph format that is appropriate for the number of data points and variables. • Remove unnecessary clutter and effects, such as three-dimensional (3D) & shading. • Position graph labels to be read horizontally or diagonally, rather than vertically.
Clarity	• Explain clearly in the title what information the chart or graph contains, including important details such as time period or location. • Organize content so that change progresses from left to right. • Order (sort) data from high values to low values (top to bottom or left to right). • Make important information stand out (with colour, pattern and/or thickness). • Display rounded numbers (e.g., 90% vs. 89.6%). Be consistent with rounding method. • Use less than 7 colours, if possible, and ensure colours have enough contrast. Use the same colours or shapes for the same variables. • Ensure that fonts, including the legend, are large enough to read. • Specify units of measurement.
Accuracy	• Ensure that exact values are clearly labelled or can be determined, if important. • Ensure the same criteria (e.g. time period, collection system, geographic area) are used when presenting a series of numbers for comparison. • Provide a source for all numbers. If data are subject to change, include an 'as of' date. • Describe missing data, if relevant — can create uncertainty or lead to misinterpretation. • Ensure that line length & shape volume accurately reflect the numbers in schematics. • Use light colours for low values and dark colours for high values.

[27] WHO European Regional Office. Effective communication of immunization data (2019).

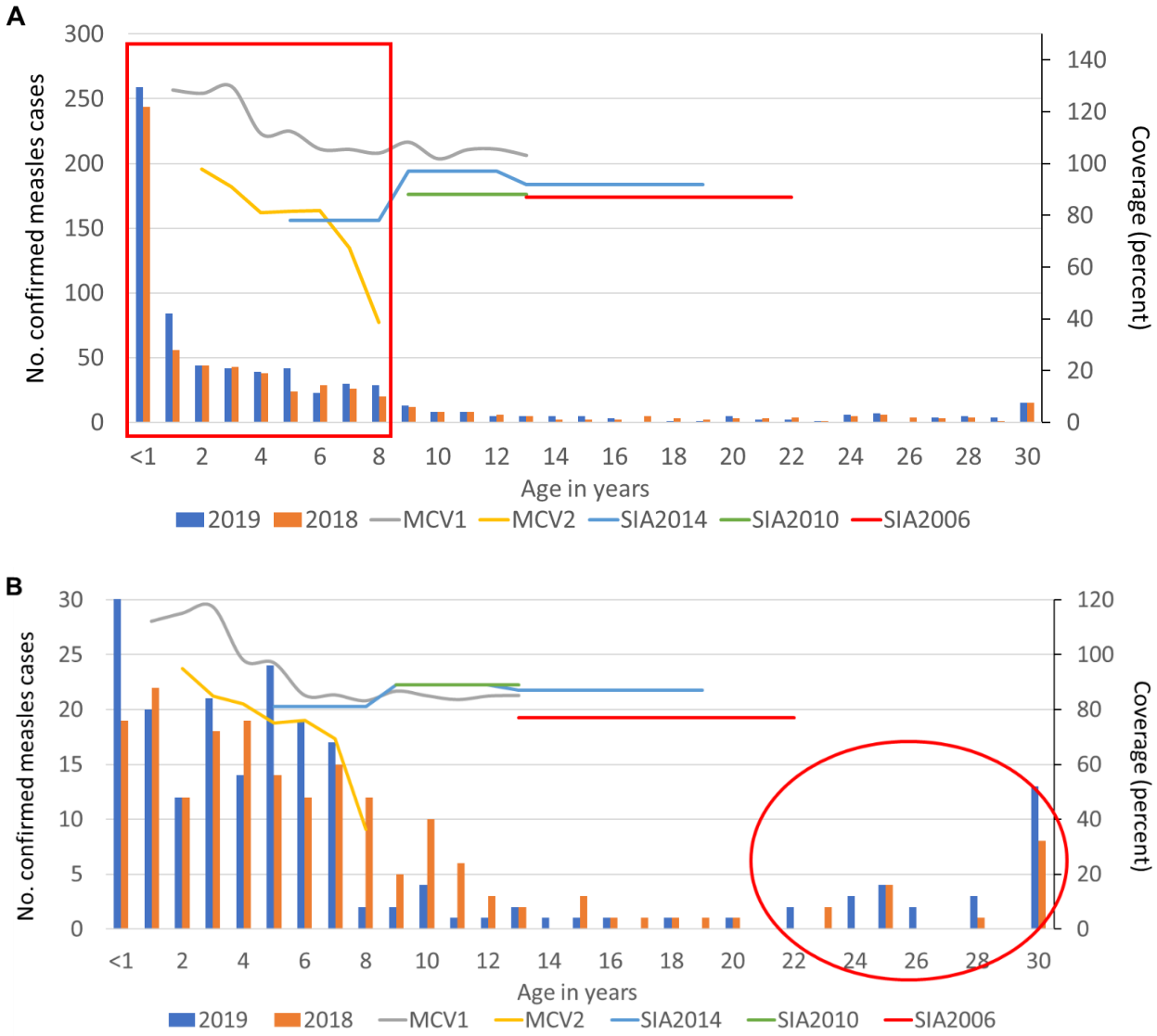


Fig. 15. Example of an age-cohort analysis of confirmed measles cases by age and historic coverage of different measles vaccination opportunities in county X, 2018–2019. MCV=measles containing vaccine; SIA=supplementary immunization activity. (A) In a highly populated district with a relatively poorly performing program, most confirmed measles cases are among birth cohorts not targeted by SIA or with recent low coverage. (B) In a district with a well-performing vaccination program, most cases occur in a similar age group, but there are fewer confirmed cases (note the different scale of the y-axis) and an epidemiological shift in the age of cases related to immunity gaps in older ages.

3.4. How to use data to plan for action

3.4.1. Data Communication

Visual information is processed faster than words and aids the understanding and memory of your audience. Visualizing data, by means of graphs, charts, icons, infographics and other formats can help you communicate complex information clearly and efficiently. Effective data visualization can help persuade your audience to take the recommended action.

Be sure to **tailor key messages to the audience** for your presentation.[13] The most effective visualizations have one main message that is recognizable at first glance. Up to several additional points can be included but going beyond that will exceed the attention span of your audience.

When developing a presentation or report, **try to tell a story with your data**. Think through the logical flow of major points that need to be made, and how these points can be supported with different strands of evidence. It is important to prioritize based on key messages, rather than overwhelming your audience with too much information. Using icons and photographs, instead of text, can make your visualization more attractive and memorable. For text, short bullets of key information are better rather than full sentences. Using **specific examples** to highlight explanatory causes for observations will make your points more memorable.

Ensure that key findings are **shared with key stakeholders**, including decision-makers, as well as different programme levels, including the level responsible for implementation. Consider what the appropriate venues are for dissemination of findings and whether different versions of the presentation/report need to be tailored to different audiences, e.g., high-level government officials, district programme managers, public dissemination through the media.

3.4.2. Developing a Plan of Action

In a presentation or report, consider ending with a **call to action** that is linked to the conclusions from the triangulation findings in order to engage the audience. Focus recommendations on what is actionable (Table 8). This means thinking about the **root causes** behind the problems that need to be addressed, i.e., "Why does this happen?" As a rule of thumb, finding the root cause may involve asking "why?" five times until one finds one or more root causes for that problem that can be tackled with concrete solutions.[28] For example, are data quality errors occurring because of poor tool design, lack of health worker motivation, or lack of a process for data validation? In some cases, a field evaluation may be needed to discover the root cause, which could be recommended as a next step.

Consider devoting a part of the dissemination meeting to developing an **action plan** and/or prioritizing recommended actions (Table 8). Based on triangulation findings, the relevant levels for **action may be at your administrative level, and/or levels above or below**. In terms of the action plan, it is suggested to develop recommended actions for each level, as relevant. **Obtain collaborative input** from people being tasked with implementation of the proposed action plan, including local authorities where possible.

Think creatively about solutions to the issues identified, especially if resources are limited. Multiple approaches be relevant to address the particular programme issue. **Actions should be prioritized** for

[28] WHO. Handbook on the use, collection, and improvement of immunization data (June 2018 draft). https://www.dropbox.com/s/8ivdiu0g5xvnlbc/handbook.pdf?dl=

what is feasible for the short- and long-term, based on potential impact and feasibility, i.e., what will take more time to address.

After implementation of the plan, **considering the impact** of the specific actions will be helpful for informing future triangulation efforts and related actions. Remember that triangulation is an iterative process, rather than a one-off activity.

Table 8. Examples actions plan based on triangulation

Area	Example of actions
Identify subnational areas in need	• Field assessment to understand root cases • Targeted assistance, e.g., microplanning • Supportive supervision, e.g., data quality • Enhancing active surveillance in high-risk areas
Revise programme policy, guidance and processes	• Microplanning update, e.g., using local growth rates • Monitoring indicators & process for data validation • Supportive supervision guidance & tools
Implement targeted interventions	• Mentoring on triangulation for data quality improvement • Reinforcing timely vaccination and importance of MCV2 • Vaccination campaigns or catch-up vaccination
Raise issues to decision-makers	• Discussing with higher level supervisors • Meeting with relevant programme units

4. Other Considerations for Triangulation Implementation

4.1. Capacity building at subnational levels

In terms of building capacity for data triangulation, it is recommended to involve learning specialists in developing a training curriculum based on **adult learning theory**. For example, **practical exercises** are useful to apply new data triangulation skills to realistic immunization surveillance scenarios. Capacity-building materials are available from the WHO Scholar course on Triangulation for Immunization Programme Improvement[29] and by request (EPItriangulation@gmail.com).

To build country capacity, we recommend incorporating explanations and exercises on triangulation within **widely used immunization training modules**, e.g., Reaching Every District (RED), Mid-level Managers (MLM), Immunization in Practice. As a first step, consider training those who could help lead trainings and mentorship, e.g., mid-level programme managers, Surveillance Medical Officers, Field Epidemiology Training Program Fellows, and Stop Transmission of Polio (STOP) officers.

Mentorship, peer-learning, and reinforcement through **feedback** may all be relevant modalities for building triangulation skills. Where immunization partners are involved in capacity building, it is recommended to define in advance their specific contributions so that national staff are fully ready to support interactive and impactful training.

Some learners may require prerequisite training on common data analysis tools, such as Microsoft Excel and DHIS2. If relevant, basic analysis training could be included before triangulation as part of the same training. Tools for this type of capacity building are outside the scope of this guidance, but resources are listed in the Appendix B and free online tutorials can also be identified by searching

[29] WHO Scholar Course on Triangulation for Immunization Programme Improvement. Materials in English: https://tinyurl.com/2020-triangulation and French: www.tinyurl.com/triangulation-2020

online. Some special training needs on geospatial analysis in QGIS software and Excel examples of performing age cohort analysis will be available as part of the triangulation capacity-building resources.

4.2. How to build triangulation into the data use culture

In terms of improving data use, a recent review has shown that multi-component interventions, rather than single interventions work best.[30] For example, incorporating triangulation into guidance, training, mentorship, and routine feedback. A list of examples is below. We are not suggesting doing *all of the activities,* but rather to consider incorporating triangulation into the programme in multiple different ways to allow for the possibility of greater sustainability and impact.

Examples of how to incorporate triangulation into a broader data use culture[31]

Leadership and governance

»» Invitation to triangulation workshops of political champions that promote data use at different level of the health system.
»» Involvement of NITAGs, different government units (statistics, information systems, surveillance), and civil society organizations, and universities in triangulation exercises.
»» Formal policies cite the importance of triangulation as part of data-enabled evidence generation.

Strategy and investment

»» Incorporation of triangulation approaches into data systems, data use strategies, data improvement are included in plans and budgets.
»» Immunization partner investments and technical assistance for triangulation are coordinated and driven by government priorities.

Services and applications

»» Triangulation applications are incorporated into endorsed data platforms and supported by strong change management strategies throughout the health system.

Standards and compliance

»» Clear guidance on triangulation is incorporated into guidelines and standards on data analysis and use, as well as frameworks for monitoring immunization programme and surveillance performance.
»» Mechanisms are in place to ensure triangulation guidance is implemented (e.g., monitoring).

Workforce

»» Continuous in-service capacity-building on triangulation (via routine meetings, supervisory visits) as part of broader skills in analysis, management, and use of data for planning, service delivery and policymaking.
»» Decision-makers are included in training on triangulation for using data effectively.
»» Peer networking is leveraged to improve triangulation and data use at all levels.
»» Incentives are provided to health staff to use triangulation of data to improve planning and service delivery (e.g., certificates, positive feedback from supervisors).

4.3. Triangulation during emergencies

Because of use of available data sources, triangulation allows for relatively **rapid understanding** of the situation and facilitates timely and appropriate decision-making during health crises. Time to provide capacity-building on performing triangulation may not be feasible, so prospective training of staff on triangulation with emergencies situations in mind is advised.

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[30] Immunization Data: Evidence for Action (IDEA) Report (2019): https://www.technet-21.org/en/topics/idea
[31] Arenth B et al. Defining and Building a Data Use Culture (2017): http://bidinitiative.org/wp-content/uploads/PATH_Building-Data-Use-Culture_R1.pdf

Collaboration with different partners related to the emergency is important for determining relevant questions, and for obtaining access to data and input on data interpretation and use for decision making. Examples of relevant **partners working in emergency settings** include:

»» WHO Health Emergencies (WHE) Programme
»» United Nations (UN) Office for the Coordination of Humanitarian Affairs (OCHA)
»» UNHCR, the UN Refugee Agency
»» International Organization for Migration (IOM)
»» International Federation of Red Cross and Red Crescent Societies (IFRC), and national societies
»» World Food Programme (WFP)
»» Local non-governmental organizations providing health services and supplies to displaced persons

In terms of **information useful during emergencies**, these partners may use *satellite imagery* to assess affected areas, create *annotated maps* of areas that are inaccessible or having displaced persons, *estimate populations* of displaced persons, and report on *disruption of health service*. Situation reports, more commonly referred to as **SITREP**s, are produced at routine intervals by partners during emergencies and are usually great sources of information.

During times of emergencies, **VPD outbreak response** data may be organized by partners and require coordination to access. In addition, the **polio eradication programme** routinely works in high-risk areas and may have information that is useful, like *maps of inaccessible areas*, *rapid coverage assessments* with numbers and percentage of zero-dose children, including from interactions with families who are on the move (e.g., in markets, crossing borders, nomadic, internally displaced). The polio programme has many great examples of triangulation of coverage, surveillance and contextual information for the purpose of reaching every last child[32] [33].

5. Conclusions

By building or strengthening triangulation capacity within EPI, existing data can be better used for decision-making to improve immunization and surveillance programmes. Triangulation of data from multiple sources helps identify areas where data quality can be improved. In addition, the conclusions reached through triangulation can provide stronger evidence for planning, management, and changes in programme policy and strategy towards the goal of reducing the number of unvaccinated children and the incidence of VPDs. Developing EPI data triangulation capacity has the potential to reinforce broader use by other priority public health programs and is hoped to assist with strengthening capacity of the health system in countries.

Suggestions for how you can start *now*

What are several things you have learned that you would like to carry forward? What are some opportunities in your work where triangulation could be incorporated? You can write out a plan now and carry it out. Some other simple suggestions to get started with practicing triangulation:

»» Use all of the data you have available, including vaccine stock and surveillance
»» Talk to colleagues to discover additional data sources that could be helpful

[32] Borno State, Nigeria: Assessed Settlements and Polio Vaccination Reach (Jan 2016 – Dec 2016) https://ij-healthgeographics.biomedcentral.com/articles/10.1186/s12942-019-0175-y

[33] Dashboard of the Polio Information System. http://polioeradication.org/wp-content/uploads/2016/07/GPEI-global-polio-surveillance-action-plan-2018-2020-EN-1.pdf

»» Make efforts to collaborate more across programme units and organizations
»» Ask more questions — to drive analyses and discover the root causes of problems
»» Brush up your analysis skills by reading tutorials and videos online (Appendix B)
»» Incorporate several of your favorite data visualization hints (Appendix B)
»» Identify multiple alternative explanations for results, including data limitations (Appendix C)
»» Brainstorm different possible data-guided actions, the relative impact, and related assumptions
»» Ask for feedback on your work from colleagues who are good at analysis or presentations

Appendix A. Detailed 10-Step Process for EPI Data Triangulation

Fig. 1.1. Three phases of an in-depth triangulation exercise.

This Appendix provides a more detailed description of the 10-step process for data triangulation and practical considerations that will be helpful for conducting larger analyses projects. The steps are categorized into three phases of implementation: Prepare, Analyze, and Act (Fig 1.1). For orientation, the steps below are color-coded based on the phases in Fig 1.1.

Identify the key question / issue

Engagement of a multi-disciplinary team from the beginning is encouraged to aid in formulating the question(s) for triangulation and identifying data sources. Involving partners with diverse areas of expertise (e.g., surveillance, health information, demographers, refugee health officers) from different units of the government, non-governmental organizations, and NITAGs has the potential to allow access to different data sources and a more informed interpretation of results. It is also important to include decision-makers, who will use the information, from the beginning.

Thus, the first potential triangulation activity is to hold a meeting with stakeholders. The meeting should be led by the immunization program, with relevant partners and subject matter experts, in consultation with any triangulation experts. The meeting facilitators may present an overview of triangulation, including examples. Then, the group can brainstorm key issues and questions that need to be answered, as well as relevant existing data sources. See **Section 3.1** for advice on how to ask the key question.

The following broad programmatic areas and/or related performance improvement efforts are relevant for use of EPI triangulation approaches:

1) Data quality (e.g., coverage, vaccine supply/use, denominators, surveillance)
2) Immunity gaps and disease risk (e.g., age-groups, geographic areas, high-risk populations)
3) Programme performance and risk (e.g., coverage, vaccine use/supply, surveillance)
4) Programme effectiveness and impact (e.g. on disease burden, health system)
5) Progress towards disease elimination and control goals.

Identify data sources

The next step is to identify existing data sources and determine their relevance to the chosen question(s), based on discussions with colleagues and follow-up investigation. Use of diverse data sets is recommended. See **Section 3.2** for other considerations around choosing data sources.

Making an **inventory table** of the data sources that summarizes key aspects like data collection method, time period, population/ geographic area, and data quality issues that may be relevant is often helpful (Table 1.1). Creating an electronic **archive** of the compiled data will facilitate current and future use.

Table 1.1. Example of an inventory table of existing data sources

Data source	Data collection method	Reporting Frequency	Population/ geography	Years	Information used for	Access	Data quality issues	Location/ notes on status

Table 1.2 summarizes criteria to consider while reviewing available data sources for consideration in the triangulation exercise. Strengths and limitations are associated with different data collection methodologies, and therefore each data source. A summary of strengths and limitations of some example data sources is in Appendix C. It is important to have an initial understanding of the data quality and other limitations of the data sources compiled and consider if triangulating the available data sets could adequately answer the identified question(s).

Table 1.2. Review Criteria for Assessing the Quality and Usefulness of the Data[34]

Criteria	Key Points
Access	• Can permission be obtained to use data? • What format are the data in (e.g. aggregate, line list)?
Description of data	• What type of data was collected (qualitative or quantitative)? • When were the data collected? • Who collected the data? • Are the data relevant to the key questions being asked?
Data quality	• How complete is the data? What are the gaps? • What is the quality of the data? • What are the limitations or biases in the data?
Ethics	• Was the data obtained according to ethical standards?

Access. Consideration of access to data sources is important. Some entities do not readily share data, so engage the relevant stakeholders in the triangulation exercise to ensure that the identified data sources can be accessed and adequately interpreted. Additionally, data must be in a format that can be analyzed. Some data are only available through summary reports or in aggregate form that does not allow for the relevant analyses. Other data may be incomplete or need cleaning.

Description of data. To successfully interpret triangulation results, the analyst(s) must understand the data being used. Collect relevant documentation (e.g., protocols, guidelines, forms) to facilitate detailed understanding of the data collection methods. Discussions with local staff may be necessary to understand how the data are collected and used, as well as any known limitations (like changes in data collection methods within the relevant time frame).

Data quality. While in-depth analysis of the quality of each data set will be performed later in the process (Steps 5 and 6), an initial understanding of data quality and limitations of the data sources is important to evaluate whether the data source is appropriate for answering the identified question. Much of this information should be in available through documentation and discussions with relevant staff. Stakeholders will need to consider if the overall quality of each data set renders it

[34] World Health Organization (WHO). HIV triangulation resource guide (2009). https://globalhealthsciences.ucsf.edu/sites/globalhealthsciences.ucsf.edu/files/pub/gsi-tri-oms-hiv-triangulation-guide.pdf

unusable; if the data quality issues can be overcome by triangulation with other data sources and the data set can remain as is; or if the data quality issues require data cleaning prior to triangulation.

Ethics. Standards of professional conduct, practice and data collection methods should be considered when evaluating data sources used in triangulation. The ethical standards followed should consider the applicable national, state and local laws, as well as international standards, if applicable. Depending on who is conducting the analysis, consider whether deidentification to protect the confidentiality of personal information should be applicable.

Refine the analysis question(s)

After identifying data sources and key information about the data, stakeholders will have a better understanding about the limitations of the available data. It can be decided if including specific data sources would allow for the interpretation necessary to answer question(s) identified. At this stage, stakeholders should revise and refine initial ideas to questions that are **important, answerable, actionable, appropriate, and feasible** (Table 2, Section 3.1). See **Section 3.1** for related points.

Questions not meeting the criteria should be further refined to **limit the scope** to questions that are important, can be answered, and can be acted upon. Some examples of potential key questions that can be addressed by conducting an EPI triangulation exercise are given in Table 1.3.

Table 1.3. Examples of potential EPI triangulation questions

Routine triangulation for monitoring performance to inform programme management
Where are zero-dose and under-immunized children?
What are the high-risk groups for VPDs?
What are the barriers to vaccine acceptance and demand?
Where should supervision and resources for strengthening immunization or surveillance be targeted?
What is the extent of issues with current vaccine/supply forecasting and stock-outs?
What is the extent of immunization data quality issues (numerator and population denominators)?
Ad-hoc triangulation for evaluating programme effectiveness and impact to inform strategy
Is the routine immunization programme (or SIAs) reaching high-risk groups?
Does there need to be a change to the current vaccine schedule recommendations?
What is the impact of a new vaccine introduction on disease burden?
How are we progressing towards disease elimination targets?
What is the *real* vaccination coverage at the national/sub-national level?

If multiple important questions are raised, it is acceptable to address **multiple questions** within the triangulation activity; the findings may complement one another. However, it is important to note that including multiple questions is likely to increase the amount of time and resources needed to complete the activity.

Gather and prepare data

The most **time-consuming** and resource-intensive step of triangulation is gathering the different data, cleaning, and putting the data into a **usable format**. Not all data will be in a database; rather, some may reside in report tables. Qualitative data may be in formats that require extra time to review and prepare (e.g., reports, transcripts).

This step requires a lot of **coordination** and **data management**, so it is recommended that at least one point-person is assigned to manage the completion of this step. For greatest efficiency, ensure that organizational representatives are invited to participate in the triangulation exercise early in the

process. The point person(s) for gathering and preparing data will need to work with focal points within organizations housing each data source to ensure data authorization or access is obtained.

Continued correspondence with organizational focal points may be necessary to gather and refine the data or seek feedback on observations during the rest of the triangulation exercise. Data will likely need to be cleaned to ensure the data sets are in a format that allows for cross-observation.

It is also important for the triangulation stakeholders to develop a process for **monitoring the progress** of data collection/consolidation and preparation. The process could include regular meetings with the triangulation data analyst(s) and points of contact within the organizations maintaining the necessary data sources.

A best practice for the triangulation analysis phases is to develop a detailed analytic plan (e.g., list of outputs, variables for comparisons, dummy tables, etc.) and to adhere to it as much as possible during the analysis.

Examine the reliability of the data

The first analysis task is to assess the **reliability of each data source**. This includes the data collection method (e.g., population-based surveillance, survey sampling), sample size, and sources of potential bias (e.g., non-response), and data quality. In general, greater weight is given to data with collection methods designed to ensure representativeness of the population (e.g., surveys, surveillance, programme data). However, lower quality studies should not be completely dismissed. General guidance on ranking the confidence of each data source is provided in Table 1.4, but this could change based on four **criteria**: sampling method (representative of the population or not), bias (see box below), sample size (large or small), and data quality (e.g., collected in a consistent manner).

Table 1.4. Classifying reliability of data sources by confidence level, based on methods[6]

Confidence level (1=highest, 5=lowest)	Data sources	Data collection method
1	• National epidemiologic surveys • Official census	Data from large standardized epidemiological surveys (DHS, MICS, etc.) and official censuses should be given the highest level of confidence.
2	• Disease surveillance case reporting, outbreak line lists	Disease surveillance case reporting, if collected through standardized methods, should be given the next level of confidence.
3	• Programme data	If collected through standardized methods, programme data should be given the next highest level of confidence.
4	• Experimental research studies	Clearly summarized conclusions from peer-reviewed scientific research studies should be given the next level of confidence as they are generally not nationally representative and almost never answer the triangulation question directly.
5	• Non-experimental studies • Unpublished / non-peer reviewed studies and reports	Lower confidence should be given to studies conducted based on nonexperimental methodologies, including qualitative studies.
6	• Studies with unclear methodologies or uncertain quality	Lowest confidence as quality cannot be ascertained.

Understanding the Effect of Bias

Bias is any systematic error in data collection that results in an under- or over-estimation a health outcome (e.g., vaccination, VPD incidence) or risk factor associated with a health outcome.

Selection bias occurs when the people included in the data do not reflect the overall population. For example, doing a survey of tetanus vaccination among women who attend antenatal care visits may overestimate coverage as pregnant women regularly get vaccinated during this time.

Information bias occurs when key information is either collected, measured, or interpreted inaccurately. For example, relying heavily on maternal recall rather than vaccination cards during a vaccination coverage survey could cause inaccuracies in estimating the coverage.

Confounding bias occurs when two factors are associated with each other and with the variable of interest. An example would be associating a large decrease in typhoid incidence with vaccine introduction in March, when a water treatment intervention also occurred in March and likely also reduced disease incidence.

For analysis of **data quality**, existing guidance exists on conducting **simple desk review** (see Toolkit below). Indicators of *reporting completeness* at the district and facility level should be reviewed and generalizability considered (i.e., who is missing). *Internal consistency* should be evaluated by looking at the variation in values across geographic areas and over time, and any missing data. A critical view should be taken of *silence* (zero and non-reporting) and any outliers, such as any deviations from expected programme values (e.g., >100% coverage) or expected epidemiology. Examining consistency with related indicators (e.g., doses provided at same opportunity, dropout) is helpful. See **section 3.3** for other related points.

Toolkit of Resources for Assessing Data Quality

WHO. Data Quality Review Toolkit (2019): https://www.who.int/healthinfo/tools_data_analysis/dqr_modules/en/

Analysis and use of health facility data: Guidance for Programme Managers (February 2018 working document): https://www.who.int/healthinfo/tools_data_analysis_routine_facility/en/

WHO. Handbook on the use, collection, and improvement of immunization data (June 2018 draft): https://www.dropbox.com/s/8ivdiu0g5xvnlbc/handbook.pdf?dl=1

PAHO. Tools for monitoring the coverage of integrated public health interventions: Vaccination and deworming of soil-transmitted helminthiasis (2017): http://iris.paho.org/xmlui/handle/123456789/34510

WHO. Assessing and Improving the Accuracy of Target Population Estimates for Immunization Coverage (November 2015 draft): https://www.who.int/immunization/monitoring_surveillance/data/Denominator_guide.pdf.

Step 6

Compare trends across data sets

The next task is to compare the **consistency and trends across data sets**, or *external consistency*. For a single time-point, note whether the data *agree, disagree or are silent*. Across data sources, geographic areas and population groups. Across geographic areas and sub-population groups, note the consistency of trends over time.

To interpret how different data sources relate to each other, a deeper understanding is needed of the relationship between indicators, as well as the limitations of data sources (Table 6 and Appendix C). Suggested dos and don'ts of data triangulation are included in Table 5. See **Section 3.3** for related points and Annexes 2, 3 and 4 for more detailed guidance on specific topics.

Consider explanatory causes (including sources of error)

To **consider different explanatory causes** for the observed trends is essential to strengthen your interpretation and draw the best conclusions. In triangulation, we are searching for possible explanations that are consistent with most of the data and appear to be valid. This process includes formulation of hypotheses that could explain your observations.

In practice, the triangulation analysts should arrange a **brainstorming exercise** using compiled data and evidence and question the data to develop possible explanations. For example, are changes in performance noted in areas that have been recently targeted for improvement, or with known issues? Did the intervention precede the change in performance?

It is also important to evaluate **alternative explanations** for the data trends, including coincidence, and data limitations and errors that could lead to bias (see box above). Data that does not fit your favorite hypothesis should not be discarded; **closer consideration of discrepancies can lead to new hypotheses and deeper understanding** (Table 5). Alternative explanations might require gathering additional data to corroborate or refute these alternatives, as described in Step 8. If data do not exist, it is important to include this alternate possibility in your conclusions and note the need for additional information.

It is important to discuss your findings in the light of the **strengths and limitations** of the data triangulation exercise and individual data sources used, including any potential missing information and sources of error. In triangulation, conclusions are drawn based on the repetition of findings from multiple data sources, often using different types of methodologies.

If necessary, identify additional data (go back to step 4)

Triangulation is an **iterative process**, where explanations are refined until they best match the whole of the data. Throughout this process, it is important to consider whether **additional data** are available that would be useful and need to be gathered. Triangulation can be thought of like **detective work**, with each new clue or data point serving to confirm or disprove your working hypothesis, leading you to search for additional data or alternative explanations.[35]

If relevant existing data is identified, it would be necessary to repeat the analysis Steps 4–8, until your interpretations are supported by all of the data; then, the data triangulation analysis process is complete. If a gap in information exists, areas for future research could to noted where helps is needed to answer the question more thoroughly.

[35] World Health Organization (WHO). HIV triangulation resource guide (2009). https://globalhealthsciences.ucsf.edu/sites/globalhealthsciences.ucsf.edu/files/pub/gsi-tri-oms-hiv-triangulation-guide.pdf

Step 9 Summarize results and conclusions (including data limitations)

The final two steps of the data triangulation process summarize the results and conclusions of triangulation so that they can be used for planning and decision-making. At this stage, analysts should decide which interpretations are supported by the maximum number of data sources. Analysts and other subject matter experts should also sort through the analyses frame the key findings into simple **messages tailored to different target audiences**.

Think through what you have learned through the exercise and attempt to **tell a story** with your data. Because visual information is processed faster than words, using clear and simple graphs and charts, accompanied by 1–3 bullets of key messages, can be an effective way to convey the information. Develop a logical flow of points, supported with explanatory details, including specific examples that explain your findings and make them more memorable. See **Section 3.3** for more details. Think through and propose a list of recommended actions for different levels based on triangulation results.

In practice, it may be helpful to hold a **workshop**, which provides stakeholders from various disciplines and organizations the opportunity to review the data and provide insights. This exercise should involve reviewing and synthesizing the results, limitations, gaps in information, conclusions and recommendations. Analysts should note of any further data or investigation (e.g., root cause analysis) needed done to strengthen the hypotheses. In addition, highlighting any gaps in data quality, which could be fed into the action plan.

Step 10 Communicate results and discuss plan of action

As outlined in this document, triangulation for national EPI and VPD surveillance programmes can be outlined as a 10-step process that starts with identifying the key public health questions and ends with **communicating results** and developing a plan for public health action. Analysts should disseminate the report to key stakeholders, who should be engaged in developing a **plan of action** based on the results. See **Section 3.4** for more details.

The recommended actions may be for any administrative level. It is recommended to obtain input from the relevant programme managers and people tasked with implementing the plan. Think creatively about solutions if resources are limited. Prioritize based on what is feasible for the short and long-term. The plan of action should provide details on the activities, roles and responsibilities, persons in charge, resources required to address the results and recommendations from the data triangulation exercise.

Triangulation performed as part of **routine monitoring** may not require dissemination beyond a supervisor responsible for programme planning and empowered to make decisions on programme priorities. **Results of routine data analyses should inform programme action**. Using evidence to tailor programme activities will strengthen the cycle of continuous quality improvement.

For a more **formal triangulation exercise**, analysts should develop a **report or presentation** at the final stage of the process to summarize the results, including graphs and likely explanations for trends, and any recommendations (see report outline below). Limitations and gaps in information should be clearly documented, preferably in a table by data source. Include the plan of actions based on the results, or how the results of the triangulation were already used, i.e., for change in policy/strategy, programme planning or management. This will help document impact and provide a basis for allocating resources for future similar activities.

Outline for a report (or presentation) on triangulation process and findings[6]

1. Describe key analysis questions and how they were selected.
    i. Include any initial hypothesis you made prior to data analysis.
2. Describe data sources and methods used.
3. Present data analysis findings and interpretation.
    i. Describe primary findings. Use charts, figures, graphs and maps to visually display your results.
    ii. Was your hypothesis proved or disproved based on the triangulation analysis? State any new hypotheses that arose.
    iii. Summarize other secondary results (not related to main questions).
    iv. Describe data interpretations, including contextual information and any case studies.
4. Note limitations.
5. Summarize conclusions.
6. Translate findings into:
    i. Need for additional information;
    ii. Programmatic recommendations;
    iii. Policy recommendations.

Remember, triangulation should be an iterative process, or repeated cycle. We recommend revisiting the issue of interest periodically it to see if it has been resolved or if a new programme issue has been identified. The frequency could be monthly, quarterly, or yearly and depends on the question being asked. It would also be useful to reflect upon the whether the items implemented as part of the action plan were appropriate and useful.

Appendix B: Other Resources

Immunization Data

Immunization data, statistics and graphics, WHO
www.who.int/immunization/monitoring_surveillance/data/en/

Data Monitoring and Improvement

WHO. Handbook on the use, collection, and improvement of immunization data (June 2018 draft).
https://www.dropbox.com/s/8ivdiu0g5xvnlbc/handbook.pdf?dl=

WHO. Data Quality Review Toolkit (2019):
https://www.who.int/healthinfo/tools_data_analysis/dqr_modules/en/

Analysis and use of health facility data: Guidance for Programme Managers (February 2018 working document):
https://www.who.int/healthinfo/tools_data_analysis_routine_facility/en/

PAHO. Tools for monitoring the coverage of integrated public health interventions: Vaccination and deworming of soil-transmitted helminthiasis (2017): http://iris.paho.org/xmlui/handle/123456789/34510

Gavi, the Vaccine Alliance. Analysis Guidance (2020):
https://www.gavi.org/our-support/guidelines/report-and-renew

WHO, Inequity monitoring in immunization guidance:
https://apps.who.int/iris/bitstream/handle/10665/329535/9789241516532-eng.pdf?sequence=9&isAllowed=y

WHO. Assessing and Improving the Accuracy of Target Population Estimates for Immunization Coverage (November 2015 draft):
https://www.who.int/immunization/monitoring_surveillance/data/Denominator_guide.pdf.

Data Quality and Use

Immunization Data: Evidence for Action (IDEA). A Realist Review of What Works to Improve Data Use for Immunization, Evidence from Low- and Middle-Income Countries. Seattle: PATH; Washington, DC: PAHO; 2019.
https://www.technet-21.org/en/topics/idea

Report of the SAGE Working Group on Quality and Use of Immunization and Surveillance Data (2019):
https://www.who.int/immunization/sage/meetings/2019/october/presentations_background_docs/en/

World Health Organization. Meeting of the Strategic Advisory Group of Experts on Immunization, October 2019: Conclusions and Recommendations. Wkly Epidemiol Rec 94 (2019).
https://apps.who.int/iris/bitstream/handle/10665/329962/WER9447-eng-fre.pdf?ua=1

Bloland P, MacNeil A, 2019. Defining & assessing the quality, usability, and utilization of immunization data. *BMC Public Health*, 19: 380. https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-019-6709-1

Arenth B et al. Defining and Building a Data Use Culture. Goertz H, ed. Seattle: PATH; 2017. Available at:
http://bidinitiative.org/wp-content/uploads/PATH_Building-Data-Use-Culture_R1.pdf

Data Triangulation

WHO, UNICEF and U.S. Centers for Disease Control and Prevention. Public Health Data Triangulation for Immunization and Vaccine-Preventable Disease Surveillance Programmes: Framework (draft). 2019.
https://www.learning.foundation/vpd-triangulation-draft

Gavi, the Vaccine Alliance. Analysis Guidance (2020). https://www.gavi.org/our-support/guidelines/report-and-renew

John Snow Inc. Data Triangulation: Use of Health Facility Immunization Reporting Tools (2017). Available at:
https://www.jsi.com/resource/data-triangulation-use-of-health-facility-immunization-reporting-tools/

Rutherford GW, McFarland W, Spindler H, White K, Patel SV, Aberle-Grasse J, et al. Public health triangulation: approach and application to synthesizing data to understand national and local HIV epidemics. BMC Public Health. 2010;10:447. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2920890/pdf/1471-2458-10-447.pdf

UNAIDS. An Introduction to Triangulation. Geneva: UNAIDS; 2010. https://www.unaids.org/sites/default/files/sub_landing/files/10_4-Intro-to-triangulation-MEF.pdf

World Health Organization (WHO). HIV triangulation resource guide: synthesis of results from multiple data sources for evaluation and decision-making. Geneva: WHO; 2009. https://globalhealthsciences.ucsf.edu/sites/globalhealthsciences.ucsf.edu/files/pub/gsi-tri-oms-hiv-triangulation-guide.pdf

Data Communication

WHO European Regional Office. Effective communication of immunization data (2019). http://www.euro.who.int/en/health-topics/disease-prevention/vaccines-and-immunization/publications/2019/effective-communication-of-immunization-data-2019

Makulec A, 2014. Identifying your audience and finding your story, JSI Center for Health Information, Monitoring & Evaluation: https://www.slideshare.net/AmandaMakulec/identifying-your-audience-40086476

Evergreen SDH. Presenting Data Effectively: Communicating Your Findings for Maximum Impact (2nd edition). Thousand Oaks: SAGE Publications, Inc; 2017.

Data Visualization

Depict data studio. Data visualization design process: A step-by-step guide for beginners https://depictdatastudio.com/data-visualization-design-process-step-by-step-guide-for-beginners/

Depict data studio. Interactive Chart Chooser https://depictdatastudio.com/charts/

Evergreen Data. How to build plots in Excel: https://stephanieevergreen.com/how-to/

The Data Visualization Catalogue https://datavizcatalogue.com/index.html

Data visualization principles and chart types https://material.io/design/communication/data-visualization.html#style

Data visualization – How to pick the right chart type? https://eazybi.com/blog/data_visualization_and_chart_types/

The Use of Data Visualization in Government http://www.businessofgovernment.org/sites/default/files/The%20Use%20of%20Visualization%20in%20Government.pdf

An Introduction to Data Visualization: How to Create Compelling Charts & Graphs [Ebook] https://blog.hubspot.com/marketing/data-visualization-guide

Data Visualization 101: How to Design Charts and Graphs https://cdn2.hubspot.net/hub/53/file-863940581-pdf/Data_Visualization_101_How_to_Design_Charts_and_Graphs.pdf

Evergreen Data blog mostly based on use of Excel: https://stephanieevergreen.com/blog/

Evergreen SDH. Effective Data Visualization: The Right Chart for the Right Data (2nd edition). Thousand Oaks: SAGE Publications, Inc; 2020.

Guidelines for presentation of surveillance data. Stockholm: ECDC, 2018 https://ecdc.europa.eu/sites/portal/files/documents/Guidelines%20for%20presentation%20of%20surveillance%20data-final-with-cover-for-we..._0.pdf

Appendix C. Strengths and limitations of different data sources

Table C-1. Immunization data sources

Data sources	Strengths	Potential limitations
Administrative vaccination data	• Potentially includes all vaccinated children • Available at subnational level • Historic national data reported through Joint Reporting Form (JRF) available online: https://www.who.int/immunization/monitoring_surveillance/data/en/	• Missing anyone not included in reporting (e.g., private providers) • Data quality issues from recording and reporting errors • Coverage impacted by inaccuracies in both numerator & denominator • Note any changes in data reporting practices related to switching to new electronic information systems that could limit comparisons across years
Vaccine stock data	• Potentially includes all doses given • Widely available	• Missing vaccine doses not included in reporting (e.g., private providers) • Data quality issues from recording and reporting errors • Records may not be maintained on timely basis, or be worse quality than vaccination • Note any changes in data reporting practices related to switching to new electronic information systems that could limit comparisons across years
Coverage surveys	• Usually considered more reliable than administrative coverage • May include reasons for non-vaccination, other helpful information • Historic national data reported through JRF available online: https://www.who.int/immunization/monitoring_surveillance/data/en/	• Conducted periodically (e.g., every 5 years), may be unavailable for level of interest • Requires reviewing differences in methodology and quality indicators (card availability) to make comparisons across surveys and years • May exclude key hard to reach to reach or vaccinate populations (e.g. nomadic groups) more likely to be under vaccinated • Can be challenging to compile relevant data from survey reports, different files
WHO/UNICEF Estimates of National Immunization Coverage (WUENIC)	• Should be complete for all years and available online in excel format: https://www.who.int/immunization/monitoring_surveillance/data/en/ • Considered more reliable than administrative coverage	• Grade of confidence may vary (can review in country pdfs) • Subnational estimates not available, except in some countries using a WUENIC-like draft methodology from WHO
Campaign vaccination coverage	• Useful for interpreting data for diseases with control, elimination and eradication programs	• Can be challenging to compile relevant data because of poor data management • Administrative coverage may be inaccurate- use survey coverage, if available
Case-based surveillance	• Available for some diseases (e.g., polio, measles, rubella, neonatal tetanus, diphtheria), based on local context • Includes lab confirmation of disease (except for tetanus) • Includes individual-level data on age & vaccination status, helpful for comparisons with coverage	• Issues with suboptimal surveillance performance (e.g., poor sensitivity, rates of lab confirmation) may limit usefulness • Difficult to sort out real absence of cases from poor surveillance quality – helpful to compare district case tallies to zero-reporting through aggregate surveillance
Aggregate surveillance	• May include reporting from all facilities • Widely available	• Limited to suspected cases only (no lab confirmation), so cannot be sure you are evaluating the disease of interest

		• Aggregate numbers of cases without age and vaccination status likely of limited relevance, except to compare to numbers of suspect cases reported to case-based surveillance • Potential issues with data quality, like incomplete reporting • Note any changes in data reporting practices related to switching to new electronic information systems that could limit comparisons across years
Programme management	• May be available in electronic format, depending on country	• Some of the data (e.g., human resources, cold chain) may need to be located/requested • Level of aggregation and poor quality may limit use
Contextual information	• Important to consider immunization schedule, history of campaigns, surveys, any changes in surveillance & reporting definitions, major events (disasters, unrest, health sector issues)	• May be challenging to assemble this information, e.g., from programme reports, information system documentation • May need to rely on local knowledge- limited by individual's recall based on time in job
Serosurveys	• Objective biological measure of population immunity • Independent validation of programme quality and performance	• Cannot distinguish between natural infection and vaccine derived immunity (except for tetanus, which has no natural immunity) • Need to consider a variety of consideration like vaccine effectiveness, duration of immunity and disease epidemiology when making comparisons to coverage • Limited by the robustness of the survey design (representativeness), quality of implementation and accuracy of laboratory testing (sensitivity & specificity)
Modeling studies	• May be more accurate than programme data alone • Likely to become available in more countries in future	• Requires technical expertise in modeling, so not widely available • Understanding the complex methodology and key assumptions that limit interpretations • More validation needed to confirm utility for programme planning
Programme reports	• Qualitative information in Outbreak Reports, data quality assessments, EPI/VPD surveillance reviews may provide useful explanations of why issues are occurring	• Can be challenging to compile relevant reports and analyze data in meaningful way • In general, qualitative information from these reports should not be interpreted quantitively
Special studies	• Can be useful to supplement routine programme data • Maybe widely available in some countries	• Quality varies based on study design • In general, experimental studies published in peer-reviewed journals are more reliable than non-experimental studies and unpublished reports • Challenging to compile relevant publication and reports

Table C-2. Population data sources

Data sources	Strengths	Potential limitations
Census projections from National Statistics Office or EPI	• Census-based figures considered gold standard • Usually calculated by skilled demographers using reliable methods (e.g., cohort method) • Growth rate included • EPI may commission own census projections for relevant programme administrative levels	• Lack of availability of birth certificates or reliance on mother's recall may result in unreliable estimates of single year age cohorts • Potential exclusion of population segments in original census due to politics or poor implementation • Unanticipated changes in migration & fertility rates since time of census • May not be available down to operational level • Inaccuracies related to projection methods (e.g., not applying age and district-specific growth rates) • Inaccuracies from applying a set infant proportion of population (e.g., 3%) across all areas • Periodic adjustments made (e.g., intercensal projections) may not be applied retrospectively causing large unnatural changes in estimates
Microplan target from EPI	• Completed at programme operational level • Usually relatively complete • Guidance & training materials usually available	• Usually calculated based on vaccine doses given (e.g., BCG) or birth registration, and may not reflect true population • Adjustments needed for growth rate of infant population, left-outs and inclusion of outsiders, but may be poorly documented • Actual implementation may differ from policy • Calculation done by least skilled staff at lowest level & aggregated through unclear process
Infant/birth registration from EPI	• Completed during interpersonal communication in field, house to house visits, or child visits to health facility • May include information on migration status	• Varies in terms of completeness by area based on workload & motivation of staff (e.g., visiting every house in field vs registering those showing up at facility) • Adjustment for issues with completeness or left-outs needed but local figures to do so may be lacking
Civil Registration and Vital Statistics (CRVS) system (e.g., from Ministry of Planning/justice)	• If well-functioning, provides complete, continuous, and reliable data on vital events and includes those occurring both in health facilities as well as communities.	• Lack of comprehensive, well-functioning CRVS systems in majority of low- and middle-income countries • Inadequate capture of community vital events leading to incomplete and inaccurate data • Varies in terms of completeness by area based on quality of implementation • Adjustment for issues with completeness or left-outs may be needed
Local censuses from Ministry of Health or National Statistics Office	• Could be very useful if implemented well and recently	• May only be available for select areas
Surveys from National Statistics Office	• Includes crude birth rates and infant mortality rates down to district level	• Issues with growth rate estimates for the target population, and area specific growth rates not used
Antenatal care (ANC), family planning (FP) or other programme data	• Programme data independent from EPI	• Relative strength of different programmes (i.e., coverage) varies by country and local area (best to check coverage results of national multi-indicator cluster surveys) • Adjustment needed to factor for difference between antenatal care and number of births
Estimates based on satellite imagery	• May include key population groups (e.g., nomadic groups) traditionally excluded from census and coverage estimates	• Consider underlying methodology, e.g., whether estimates are normalized to census projection • May only be available for selected areas

Sample registration systems (SRS)	• Sample-based approaches can reliably and continuously capture births and deaths in sampled areas and provide estimates for population sizes and demographic indicators • Can be updated regularly (every 1-2 years) with new house-to-house visits/microcensuses • Capture both facility- and community-based births	• Only implemented in limited number of countries • May not be national in scope • Data quality dependent on quality of SRS implementation
Health and demographic surveillance sites	• Closely follow a defined population in a specific catchment area over time • Continuous collection of vital events and routine updating of population size	• Limited geographic scope – may cover just one or two districts • Data quality dependent on quality of implementation

Separate Annexes with Detailed Guidance for Specific Topics:

Document 2: Immunity gaps

Document 3: Programme performance

Document 4: Programme targets (denominators)

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Disclaimer

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