CROSSING LANES:

What we can learn from other health areas to improve vaccine forecasts for zero-dose children

OVERVIEW OF FORECASTING FOR VACCINES

Demand forecasting is the process of estimating the needed quantities of products based on a number of inputs, including demand for the product, supplier information, and other external factors such as weather patterns or other disruptive events, in order to predict the future product need. There is no single approach to forecasting for health products; various methods have been adopted by different health programs to obtain a more accurate forecast. For immunization programs, strategic national level forecasting is done on an annual basis to estimate the needed quantity of vaccines and related supplies to be procured for the following year. Estimating needs of vaccines and syringes at the tactical and operational sub-national level for re-supply efforts, including the service delivery point, is done regularly through the year, based on the distribution cycle and accounting for stock on hand.

Accurate forecasts can:

- help prevent overstock or stockouts of vaccines and other devices;
- improve the efficiency of the supply chain by avoiding emergency stock orders in the middle of a distribution cycle;
- can contribute to higher immunization coverage; and
- provide greater insight into budgeting and expected expenditures.

Standard inputs for vaccine forecasting:

Supply parameters (delivery interval, lead time)	Stock levels (safety stock, minimum/maximum levels, wastage rate)	Target population, immunization schedule, and coverage targets

The standard approach to estimating annual vaccine forecasts is using target population; two other approaches have been described but used less frequently: using previous consumption or basing the forecast on size of immunization sessions. All of these three methodologies, however, have their own challenges to estimating an accurate forecast: incomplete or inaccurate data; target populations that do not reflect realistic growth or shifting populations; and unknown session sizes. These shortcomings are exacerbated during resupply efforts for vaccine distribution to each sub-national level of the health system to the facility level; these vaccine quantities are typically based on disaggregated population data and divided evenly over the 12 months in a year. Actual consumption is not factored into annual forecasts or resupply actions, and population data does not take into account population movement and changes.

Having an accurate forecast is only one part of ensuring vaccine availability. All other components of supply chain management have to be considered – reliable transport for distribution, re-supply decisions, cold chain capacity and management particularly during transport and outreach, and application of multi-dose vial policies, to name a few.

The recent global push to focus on and reach zero-dose children (see Box 1) has shifted the importance of these challenges, as this unique population lives in the most underserved communities: urban slums, remote rural areas and conflict-affected areas. Zero-dose populations often do not access health services and may not be counted in community mapping activities or accounted for in previous estimates used for forecasting, presenting a range of immunization supply chain challenges.[1] With this shift, effort has been put into understanding the reasons behind zero-dose and underimmunized children, and guidance has been developed, largely addressing programmatic activities.[2,3,4,5]

This paper aims to build on current guidance around reaching zero-dose children to introduce a supply chain perspective, pulling experiences and case studies from forecasting and resupply in other health areas in order to explore how forecasting approaches could contribute to zero-dose efforts.

BOX 1

Gavi defines zero-dose children as those that have not received any routine vaccine. For operational purposes, it's defined as those children who lack the first dose of diphtheria-tetanus-pertussis containing vaccine (DTP1).

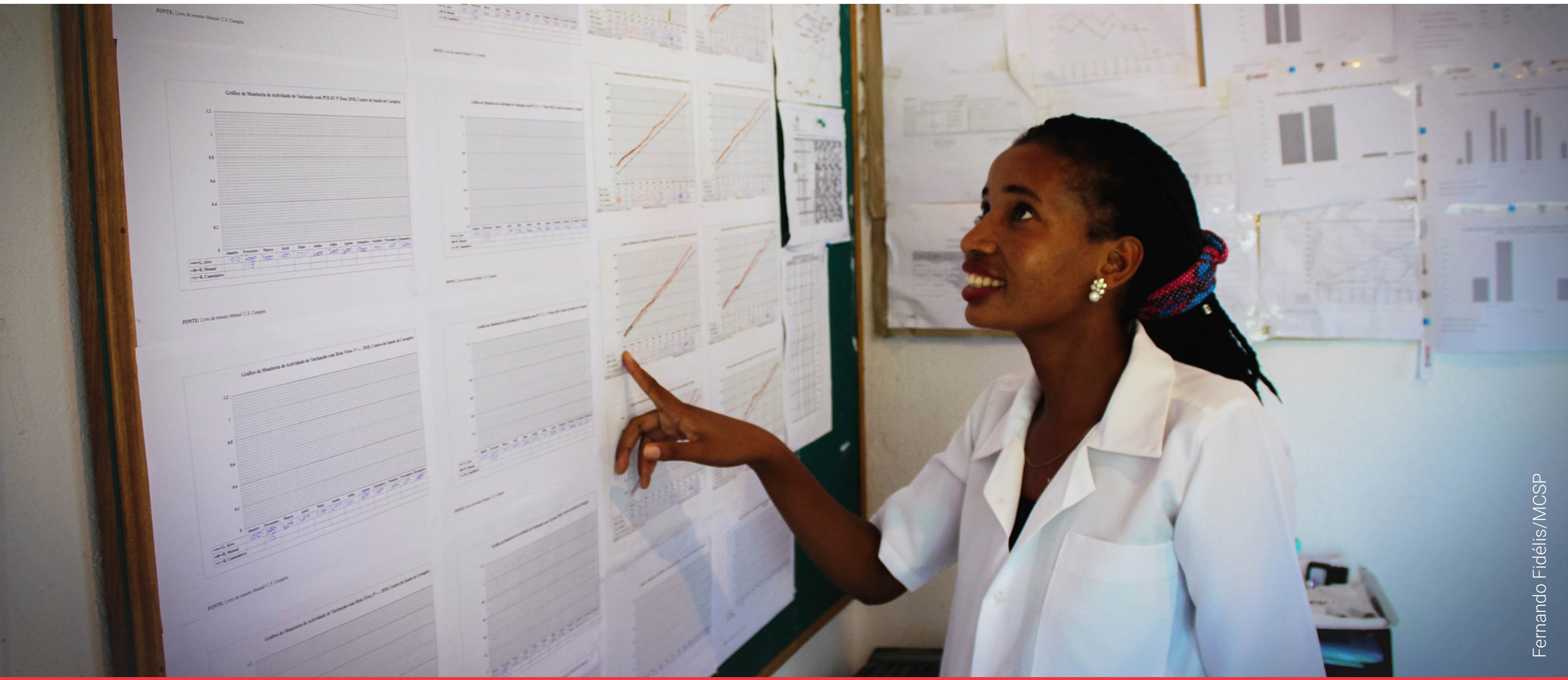
1 UNICEF Immunization Supply Chain Interventions to Enable Coverage and Equity in Urban Poor, Remote Rural and Conflict Settings https://www.unicef.org/documents/immunization-supply-chain-interventions
2 Gavi, the Vaccine Alliance. Zero-dose analysis card. https://www.linkedimmunisation.org/wp-content/uploads/2021/08/Gavi_Zero-dose_AnalysisCard.pdf. Accessed June 13, 2022.
3 Gavi, the Vaccine Alliance. The zero-dose child: Explained. https://www.gavi.org/vaccineswork/zero-dose-child-explained. Accessed June 13, 2022.
4 UNICEF. Critical mission for UNICEF: Reaching 'zero-dose' children. https://www.unicefusa.org/stories/critical-mission-unicef-reaching-zero-dose-children/39960. Accessed June 13, 2022.
5 Immunization Agenda 2030: A global strategy to leave no one behind. https://www.who.int/docs/default-source/immunization/strategy/ia2030/ia2030-document-en.pdf

CASE STUDY 1: DATA TRIANGULATION TO ESTIMATE ZERO-DOSE

Zero-dose estimates require subtracting the number of children who received DTP1 from the target population, to understand how many children were missed. However, in Mozambique where some areas have experienced repeated stockouts of DTP vaccine, this poses a challenge to ensuring accurate estimates. VillageReach conducted an analysis to overcome this obstacle through data triangulation. The number of children vaccinated across multiple vaccines (DTP1, PCV1, OPV1, and rotavirus1) – which are typically all administered at the same time as DTP1 – were compared against each other in order to assess which antigen had the highest number of children vaccinated. Using that highest estimate, a more accurate numerator for the zero-dose equation could be determined.

CASE STUDY 2: IDENTIFYING ZERO-DOSE CHILDREN IN MOZAMBIQUE

Being able to pinpoint where children and populations have been missed with immunization services is a key to addressing the zero-dose challenge and reaching those communities with vaccines. Quantifying the number of zero-dose can be a challenge, as it relies on having an accurate target population, which has been a perennial challenge to immunization programs. The Mozambique immunization program has developed a methodology to analyze the difference between the number of children vaccinated with BCG as a proxy for the target population (since BCG is typically given at birth), and those vaccinated with DPT1, as a means to more accurately identify gaps in services for zero-dose children. This avoids the inaccurate target population conundrum that is exacerbated at the district and health facility levels. Using existing data from district level administrative reporting, EPI has prioritized districts that have high numbers of children that have not returned for the first dose of DPT. This methodology does not solve all issues with identifying zero-dose children, as all children may not receive BCG, but it does provide guidance for districts, and especially health facilities, to increase efforts for micro-planning and outreach in order to identify children who are at risk. From a supply chain perspective, this improves insight into a more accurate number of children to reach at the facility level, which can then feed into resupply decisions at each higher level of the health system.



Fernando Fidélis/MCSP

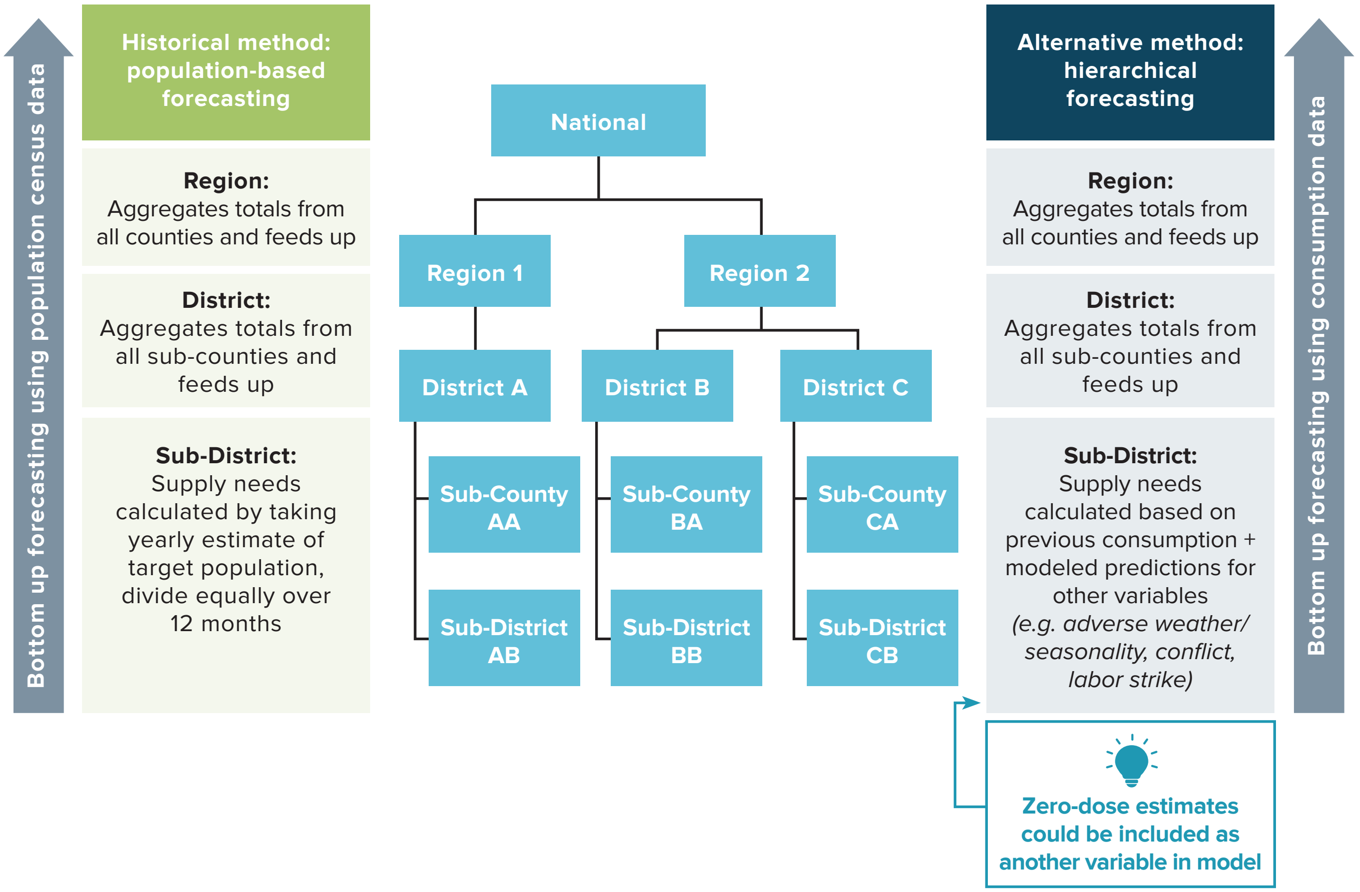
CASE STUDY 3: COMPARING TRADITIONAL AND HIERARCHICAL FORECASTING WITH A TOUCH OF COMMON SENSE TO REACH ZERO-DOSE CHILDREN

Anonymized data from a representative East African country was used to investigate the potential of using hierarchical forecasting techniques to increase the accuracy of forecasts compared with standard practice and to reach zero dose children.[6]

Historical method of forecasting: In this country, annual national-level forecasts are based on estimated target population. These estimates are derived from census data and anticipated growth and survival rates. Monthly stock needs at each level are calculated by dividing the estimated annual total population at that level by twelve. Stock is allocated to the provincial, district and facility levels through a push system according to anticipated estimated target populations and required months of supply, with 25% added as buffer stock.

This forecasting approach leads to flat estimates of stock needs for each month and at each level of the supply chain that may not necessarily correspond to actual fluctuations in demand and population movements. Further, by basing estimates on census data, the forecasts also ignore the potential for zero-dose children because these population groups may not be accounted for in official statistics. While some qualitative adjustments are made based on local-level microplanning activities, these adjustments are not applied consistently throughout the country and are not incorporated into national-level forecasting process.

Figure 1: Comparison of population-based and hierarchical forecasting for immunization



6 This work has been conducted by Associate Professor Bahman Rostami-Tabar from Cardiff University, UK.

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Alternative method of forecasting: Based on preliminary modeling and analysis, hierarchical forecasting, a form of time series forecasting that follows a hierarchical structure[7], may prove useful for vaccine demand forecasting to reach zero-dose children. In the case of the representative country, the top level of the hierarchy is the national level, with subsequent tiers at the provincial and district levels.

Rather than basing estimates of demand on target population, hierarchical forecasting can be employed to generate forecasts on monthly consumption at different levels of the supply chain.

Forecasting accurately the need across all hierarchical levels is paramount for an effective inventory policy to manage the shortage/overstock risk. The hierarchical forecasting approach can not only achieve more accurate forecasts than the historical one, but also creates consistent forecasts. Obtaining consistent forecasts at different level is important for reliable decision-making to avoid making conflicting decisions. With hierarchical forecasting plans at any level are based on identical forecasts and therefore will be aligned. The replenishment order policy and the tactical decision on inventory levels can be aligned and this also improves coordinating activities between sub-county, county, and national levels.

Hierarchical forecasting models can also be created to account for variables and predictors that affect demand, such as adverse weather events, public holidays, labor strikes, etc. Factoring-in conflict, rural poor, and migratory populations can flag certain areas as having more potential for zero-dose children. Figure 1 illustrates the differences between population-based forecasting which has been used historically, and hierarchical forecasting as an alternative method. We should note that hierarchical forecasting may take different forms. The one illustrated in Figure 1 is the Bottom-Up approach. Other approaches include Top-Down, Middle-Out and optimal reconciliation.

7 Forecasting: Principles and Practice https://otexts.com/fpp2/hierarchical.html

Comparing national-level forecast accuracy for historical data from 2015-2020 for the BCG vaccine alone showed that hierarchical forecasting was substantially more accurate than the standard, estimated population-based forecasting used in the representative country.[8] This demonstrates that hierarchical forecasting has the potential to drastically improve forecast accuracy for vaccines.

Further, leveraging recent innovations in machine learning and artificial intelligence has the potential to increase the accuracy of hierarchical forecasting for vaccines and, crucially, make it more efficient in accounting for zero dose children. Indicators will need to be developed to identify zero-dose children through collaboration with service providers and outreach programs, as well as using data from supplemental immunization activities and other sources of potential proxy data to represent zero-dose children. These indicators will allow a machine learning model to be created and trained to identify zero dose children. As demonstrated in this study, forecast accuracy improved significantly when using multivariate machine learning models to predict vaccine utilization to the facility level.[9] Incorporating zero dose indicators as part of the range of multivariate factors will enhance forecasting for zero dose children.

Further considerations: common sense with judgemental forecasting. Zero dose children are often unaccounted for in data available to immunization program managers. Judgemental forecasting techniques that rely on expert knowledge to forecast demand may prove useful for better forecasting to reach zero dose children. In particular, judgemental adjustment can be used to incorporate expert inputs into statistical forecasts where data availability or accuracy is limited. Particularly when a forecaster's relative expertise was high, the relative credibility of the system forecasts was low, and the system forecasts had a strong need of correction, judgmental adjustment has been shown to improve the accuracy relative to both other judgemental methods and the system forecasts.[10]

Judgemental forecasting is by its nature subjective and therefore a systematic approach must be followed to limit biases, misrepresentation due to personal goals, or 'anchoring' in the past. Systematically documenting the judgments and adjustments made is important to ensure transparency and accountability throughout the process.[11] Despite these constraints, combining the expert knowledge of community members and staff at service delivery points, and mobile and fixed outreach posts, could prove crucial in adjusting statistical forecasts, such as hierarchical forecasts detailed above, to reach zero dose children. Essentially, applying common sense to assumptions that build a forecast can improve its accuracy.

EXPERIENCE FROM OTHER HEALTH AREAS AND FORECASTING METHODS

Reaching zero-dose children with immunization services presents its own challenges as these children often do not access health services. From a supply chain perspective, using a few different approaches and methodologies proven successful in other health areas may be beneficial:

- Explore alternative forecasting methods such as hierarchical forecasting that will accommodate the unknown factor of zero-dose children.

8 The analysis produced significant improvements in forecasting accuracy when comparing Root Mean Scaled Squared Error (RMSSE) results between the standard and hierarchical forecasting methods.
9 An Interpretable Predictive Model of Vaccine Utilization for Tanzania https://www.frontiersin.org/articles/10.3389/frai.2020.559617/full
10 Jorge Alvarado-Valencia, Lope H. Barrero, Dilek Önkal, Jack T. Dennerlein,Expertise, credibility of system forecasts and integration methods in judgmental demand forecasting,International Journal of Forecasting,Volume 33, Issue 1, 2017, Pages 298-313,
11 https://otexts.com/fpp3/judgmental-principles.html

- Use proxy population estimates, validated at the hyper-local level and incorporated into higher level decision making.
- Document common sense factors to incorporate into future forecasts.
- Draw on a multi-stakeholder team with varied expertise using varied methods to contribute to a more accurate forecast.
- Use a rolling three-month average of monthly consumption (with anomalies such as significant stockouts, migration, conflict or global pandemics taken into consideration) to adjust the quantity and timing of procurement plans and measure forecast accuracy.
- Test out different quantities of vaccines for resupply, combining with outreach efforts, microplanning, and demand generation ideas. This was shown successful in Senegal with family planning products, with increased availability resulting in higher uptake.[12]
- Consider what data, if collected, would contribute to a more accurate forecast – for example, accurate wastage rate, session size, number of days of stockout at a facility level.

Given these options and considerations for quantifying zero-dose to adjust or improve forecasting efforts, it is critical to work collaboratively (and often across departments) at sub-national level in this process. Triangulation exercises that include health staff with different roles/departments can help bring different perspectives and collaborative problem solving.[13]

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12 https://bmchealthservres.biomedcentral.com/articles/10.1186/s12913-017-2316-y

13 Almiñana A, Bayeh A, Girma D, Kanagat N, Oot L, Prosser W, Dagnew B, Ali D. "Early Lessons From Ethiopia in Establishing a Data Triangulation Process to Analyze Immunization Program and Supply Data for Decision Making." Global Health: Science and Practice. June 2022(Vol. 10):3. DOI: 10.9745/GHSP-D-21-00719