

# Precision-Based Dengue Control Through Smart Pattern-Spotting Forecast Tools and BMRS Integration

Strengthening Baguio City's Consolidated Anti-Mosquito Borne Disease Ordinance through Predictive Dashboarding and Republic Act No. 11332 Compliance

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## Executive Summary

As part of its commitment to the UNDRR Making Cities Resilient (MCR) 2030 initiative, Baguio City aims to transform into a resilient smart city by 2026; however, its public health response to dengue remains largely reactive, relying on manual case clustering and traditional community mobilization. While the Baguio Medical Records System (BMRS/BIAG) serves the City Health Services Office (CHSO) and the Smart City Command Center, its utility is limited to descriptive reporting, which delays the early detection of localized surges and hinders full compliance with Republic Act No. 11332's mandatory disease reporting. To bridge this critical operational gap, this policy brief proposes integrating a predictive analytics engine—a "smart pattern-spotting forecast tool"—directly into the BMRS. By combining an advanced optimization method with a statistical learning model trained on historical data, this tool can automatically detect hidden trends, such as multi-

wave seasons, and project when and where the next dengue spike will occur. Linked directly to a geospatial dashboard at the command center, this framework will generate barangay-specific alert and epidemic thresholds, automate legal compliance, and guide precision vector control before outbreaks proliferate. To successfully operationalize this proactive shift, the city must institutionalize the forecasting tool via local executive action, establish a dedicated Dengue Analytics and Surveillance Unit within the CHSO, link the tool's automated risk levels to standardized operational procedures for rapid barangay response, and imbed these public health risk metrics directly into the city's broader resilience planning, budgeting, and performance management systems. Transitioning from reactive to anticipatory dengue governance optimizes resource allocation, protects vulnerable communities, and successfully aligns public health infrastructure with Baguio City's overarching smart, data-driven, and resilient sustainable development agenda.

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## Background

Baguio City has become a national reference point for smart and resilient urban governance. Through its partnership with the National Resilience Council and other stakeholders, the city has articulated a resilience roadmap centered on data, technology, and multi-sector collaboration (National Resilience Council 2019).

The Smart City Command Center, operational since 2018, aggregates CCTV feeds, traffic systems, and hazard monitoring data, and is being upgraded to incorporate artificial intelligence (AI) and advanced analytics for public safety, mobility, and disaster risk reduction (National Resilience Council 2023; Gasingan 2025). The city's four-year resilience-building plan explicitly aims for resilient city status by 2026 under MCR 2030, with a focus on integrated early warning systems and risk-informed decision-making (City Government of Baguio 2022a, 2022b, 2023).

Dengue remains a seasonal, but recurrent, public health threat. Historically, cases peak during the rainy season around epidemiologic Week 31, but recent surveillance (2020–2022) shows that earlier surges beginning near Week 27; and, multiple peaks within a single season, reflecting a hyperendemic environment where several dengue virus serotypes circulate at once (World Health Organization 2012; Department of Health – Philippines n.d.).

Rapid urbanization and densification have reshaped Baguio's microclimate and hydrology, creating mosquito breeding habitats in informal settlements, poorly serviced areas, construction sites, and flood-prone drainage systems (Good Morning Baguio 2023; City Government of Baguio 2022a). Barangays such as Irisan and Bakakeng repeatedly report localized clusters linked to water storage practices, solid waste, and drainage problems.

The city's Consolidated Anti-Mosquito Borne Disease Ordinance mandates:

- Regular household and community “search-and-destroy” drives (often at 9:00 AM);
- Elimination of standing-water breeding sites; and
- Penalties for non-compliance.

At the national level, R.A. No. 11332 requires timely, complete, and accurate reporting of notifiable diseases such as dengue, with defined roles and sanctions.

The Baguio Medical Records System (BMRS/BIAG) has significantly improved digitization of health records and basic reporting, but its current use is mainly descriptive. Data are usually viewed as city-wide or facility-level counts rather than as granular, barangay-level trends that can be forecast. This limits the city's ability to spot early warning signs and deploy “Denguerra” operations and other interventions before outbreaks escalate.

Given Baguio's existing investments in the Smart City Command Center, AI, and resilience planning (National Resilience Council 2023; City Government of Baguio 2022a, 2022b, 2023; Gasingan 2025), dengue control is a natural next area for applying smart pattern-spotting forecast tools to turn routine data into actionable early warnings.

### Policy Issue

There is a clear gap between Baguio's smart city ambitions and its current dengue control regime. On one hand, the city has: a centralized Smart City Command Center; a digitized BMRS/BIAG platform; a Consolidated Anti-Mosquito Borne Disease Ordinance; and, formal commitments to MCR 2030 and integrated early warning systems (National Resilience Council 2023; City Government of Baguio 2022a, 2022b, 2023; Gasingan 2025).

On the other hand, dengue surveillance and response still rely on: descriptive, after-the-fact analysis of case counts; manual identification of hotspots; calendar-based or complaint-driven vector control operations; and, partial, non-automated alignment with R.A. No. 11332 reporting requirements (Department of Health – Philippines n.d.).

As dengue patterns become more erratic and multi-peaked due to climate variability and urbanization (World Health Organization 2012; Good Morning Baguio 2023), this reactive approach is increasingly inadequate.

### Central policy problem:

How can Baguio City build a precision-based, predictive dengue governance system that uses BMRS data and the Smart City Command Center to: (1) detect hyperlocal dengue risks early (at *purok* and

barangay levels); (2) automatically generate compliant R.A. No. 11332 alerts and reports; and, (3) direct interventions to forecast high-risk areas in line with its smart city and resilience agenda?

## Data and Findings

### *Dengue Dynamics and Urban Risk*

Available local and national data, supported by WHO guidance, indicate that dengue transmission is strongly influenced by rainfall, temperature, and humidity, and tends to intensify during the rainy months (World Health Organization 2012; Department of Health – Philippines n.d.). In Baguio:

- Seasonal volatility has increased, with earlier and multiple peaks within a season;
- Spatial heterogeneity is marked, with certain barangays repeatedly experiencing micro-outbreaks; and
- Infrastructure and environment (e.g., drainage, waste, housing conditions) are closely tied to localized risk (Good Morning Baguio 2023; City Government of Baguio 2022a).

Similar hyperendemic settings in Southeast Asia have shown that conventional, city-wide aggregates underestimate localized risk and obscure the true burden of dengue (Undurraga et al. 2017).

### *Limits of Current BMRS Use and Response*

Despite BMRS digitization, Baguio’s dengue surveillance still faces:

- Aggregation bias – case data are commonly summarized at facility or city level, hiding early clusters in specific *puroks* or barangays;
- Descriptive orientation – routine analyses track trends after they occur rather than forecasting future surges;
- Response lag – “Denguerra,” fogging, and intensified IEC activities are often triggered only after outbreaks are obvious;
- Inconsistent R.A. No. 11332 performance – incomplete or delayed reports from some health facilities and barangays can reduce the timeliness and completeness required by law (Department of Health – Philippines n.d.).

This approach leaves the city vulnerable to sudden spikes, strains health system capacity, and reduces the effectiveness of vector control investments.

### *The “Smart Pattern-Spotting Forecast Tool”*

At the heart of this policy proposal is the use of a smart pattern-spotting forecast tool embedded in BMRS. This tool:

- Scans past dengue case data and looks for hidden patterns, such as early peaks, main peaks, and late “tail” waves;
- Automatically groups similar patterns together, like sorting neighborhoods into “early-spike” areas and “late-spike” areas based on their past dengue behavior; and
- Projects forward to estimate when and where the next increase in cases is likely to happen.

Technically, this is done by combining:

- a search algorithm that tries many possible ways to fit curves to the data and “learns” which one matches best, even when the data are noisy and patterns overlap (Storn and Price 1997; Kirkpatrick, Gelatt, and Vecchi 1983); and
- a statistical model that treats the dengue curve as a mixture of several underlying “waves” or components, each with its own timing and intensity (Addawe 2021).

Instead of a single crude threshold for the whole city, the tool can:

- build a five-year baseline for each barangay;
- calculate barangay-specific alert thresholds (e.g., when weekly cases are rising quickly toward an expected peak); and
- calculate epidemic thresholds (e.g., when cases significantly exceed what is normal for that barangay and time of year) in line with Department of Health guidance (Department of Health – Philippines n.d.; World Health Organization 2012).

Evidence from forecasting studies for influenza and other infectious diseases demonstrate that such pattern-based prediction can improve preparedness and target interventions more effectively than relying only on raw case counts (Nsoesie et al. 2014; Undurraga et al. 2017).

## Analysis

Baguio has three critical ingredients already in place:

1. Infrastructure and systems
  - a. A fully operational Smart City Command Center that already supports multi-hazard monitoring and AI-assisted analysis (National Resilience Council 2023; Gasingan 2025);
  - b. A city-wide BMRS/BIAG that captures patient and case-based data for health services.
2. Legal and policy mandates
  - a. R.A. No. 11332 requires robust, timely, and accurate reporting of dengue and other notifiable diseases;
  - b. The Consolidated Anti-Mosquito Borne Disease Ordinance mandates proactive community action and enables penalties;
  - c. The city's commitment to MCR 2030 and its four-year resilience plan emphasizes integrated early warning and data-driven decision-making (City Government of Baguio 2022a, 2022b, 2023).
3. Strategic direction
  - a. Clear political support for AI and analytics in governance and for integrating early warning systems into a single smart city platform (National Resilience Council 2023; Gasingan 2025).

The missing layer is a predictive analytics engine—the smart pattern-spotting forecast tool—firmly integrated into the BMRS and the Command Center, along with institutional arrangements and SOPs that make its outputs operational.

Without this layer, dengue control remains reactive rather than anticipatory; city-wide rather than risk-focused; and weakly connected to infrastructure planning (e.g., drainage upgrades in high-risk areas).

With this layer, Baguio can:

- Obtain advance warning (2–4 weeks) before projected peaks in specific barangays;

- Prioritize vector control resources (larviciding, fogging, barangay clean-ups) where and when they are most needed;
- Automate R.A. No. 11332 reporting with model-assisted alerts, making it easier to track anomalies and ensure compliance; and
- Better align health surveillance with ongoing resilience investments (e.g., flood control, solid waste management) in high-risk communities.

## Policy Options

1. Status Quo (Reactive, Descriptive Approach)
  - a. Continue using the BMRS mainly for recording and simple reporting;
  - b. Maintain manual cluster identification and calendar-based interventions.
    - i. *Advantages:* No new costs; minimal organizational change. *Disadvantages:* Persistent delays in outbreak detection; inefficient, city-wide deployment of resources; rising risk in the context of urbanization and climate variability.
2. Incremental Improvement without Forecasting
  - a. Strengthen completeness and timeliness of BMRS-based reporting;
  - b. Introduce simple rule-based alerts (e.g., fixed weekly case thresholds) at the CHSO level;
  - c. Develop basic maps for internal use, but without full integration into the Smart City Command Center.
    - i. *Advantages:* Moderate cost; improves data quality and basic awareness. *Disadvantages:* Still limited in forecasting ability; thresholds may not reflect local historical patterns; underutilizes existing smart city infrastructure.
3. Full Integration of a Smart Pattern-Spotting Forecast Tool into BMRS and Smart City Command Center (Recommended)
  - a. Embed the forecasting engine into BMRS to produce barangay-specific alerts and short-term forecasts;

- b. Connect outputs to a GIS-based dengue dashboard in the Smart City Command Center;
- c. Institutionalize the use of these outputs in CHSO, barangays, and DRRM operations.
  - *Advantages:* Enables anticipatory, risk-based dengue governance; leverages existing smart city and health IT investments; supports RA 11332 compliance and MCR 2030 commitments. *Disadvantages:* Requires up-front investment in model development, ICT integration, capacity building, and change management.

### Policy Recommendations

Based on the analysis above, this brief recommends Option 3 and proposes the following actions:

1. *Issue an Executive Policy to Institutionalize the Forecast Tool in BMRS.* The City Mayor may issue an executive order or memorandum that: (1) Mandates the integration of a smart pattern-spotting forecast tool into BMRS/BIAG; (2) Designates the CHSO as lead agency for dengue analytics, with the City ICT Office and the Smart City Command Center as core partners; and, (3) Explicitly links use of the tool to fulfill R.A. No. 11332 reporting duties and to enforcing the Consolidated Anti-Mosquito Borne Disease Ordinance.
2. *Create a Dengue Analytics and Surveillance Unit within the CHSO.* Establish a small, specialized unit responsible for: (1) Data quality assurance and geo-coding of dengue cases; (2) Running and maintaining the forecast tool; (3) Validating model outputs and preparing risk bulletins; Coordinating with barangays, schools, and other departments, and, Explore partnerships with local universities and research institutions for technical support and continuous model improvement.
3. *Develop a Smart Dengue Dashboard at the Smart City Command Center.* Design and deploy a dengue dashboard that shows: (1) Current dengue case counts and incidence by barangay and *purok*; (2) Forecasted risk levels and estimated time to alert and epidemic thresholds from the forecast tool; (3) Simple green–yellow–red coding for non-technical decision-makers; and, (4) Overlays of drainage networks, flood-prone zones, and other environmental risk factors. Then integrate this dashboard into regular meetings of the City Disaster Risk Reduction and Management Council (CDRRMC), Local Health Board, and relevant technical working groups.
4. *Link Risk Levels to Clear Standard Operating Procedures.* Develop written SOPs that spell out specific actions for each risk level identified by the forecast tool, for example: *Heightened Watch:* intensified case verification and community IEC; *Alert:* barangay-wide search-and-destroy, focused larvicide deployment, school and workplace IEC; and, *Epidemic:* surge in clinical response capacity, targeted fogging, multi-sector operations involving health, DRRM, engineering, environment, and education. Use forecast-based risk levels to prioritize inspections, enforcement activities, and penalties under the Consolidated Anti-Mosquito Borne Disease Ordinance.
5. *Automate and Monitor R.A. No. 11332 Reporting.* Configure the BMRS to automatically generate and transmit line lists and summary reports to the Department of Health in the required formats; and, flag barangays where case trends deviate significantly from expected patterns, prompting verification and rapid response. Track and display metrics on the timeliness and completeness of reporting for each facility and barangay, and use these metrics in performance assessments.
6. *Invest in Capacity Building and Partnerships.* Organize training for barangay health workers and facility staff on: (1) Using BMRS interfaces for timely and complete dengue reporting; and, (2) Understanding basic dashboard indicators and local action triggers. Train CHSO and Command Center analysts in: (1) fundamentals of pattern-based forecasting; and (2) interpreting and communicating model outputs and uncertainties to decision-makers and the public. Partner with universities, technical agencies, and donors to support ongoing refinement of the models and evaluation of their impact.
7. *Integrate Dengue Analytics into Resilience Planning and Budgeting.* Incorporate dengue risk maps and forecast outputs into: (1) annual investment plans for health, DRRM, engineering, and environment; local climate change adaptation and disaster risk reduction strategies; (3) performance scorecards for departments and barangays under the MCR 2030 framework.

Prioritize drainage improvements, solid waste management, and housing upgrades in barangays identified as recurrent high-risk zones for both flooding and dengue, maximizing co-benefits.

## Conclusion

Baguio City stands at a strategic moment where its smart city infrastructure, resilience commitments, and health mandates can be brought together to transform dengue control from reactive crisis management into proactive and precision-based governance.

This brief has argued that the city already possesses most of the necessary components: a functioning Smart City Command Center, a digitized BMRS/BIAG, an enabling legal framework through R.A. No. 11332 and the Consolidated Anti-Mosquito Borne Disease Ordinance, and a clear policy direction under MCR 2030 and its four-year resilience-building plan. What is missing is the predictive layer that connects these elements operationally.

Lodging a “smart pattern-spotting forecast tool” into the BMRS and streaming its outputs to a GIS-based dengue dashboard at the Smart City Command Center would provide that layer. This tool “watches” the city’s dengue data, spots hidden patterns and recurring wave shapes in different barangays, and warns decision-makers when and where the next spike is likely to appear. With barangay-specific baselines and thresholds, the city can detect emerging hotspots earlier, mobilize search-and-destroy and community actions before peaks, and deploy larvicide, fogging, and IEC efforts where they will have the greatest effect.

Institutionalizing this forecasting capability, through an executive issuance, a dedicated Dengue Analytics and Surveillance Unit, clear SOPs linked to risk levels, automated R.A. No. 11332 reporting, and targeted capacity building, would:

- Increase lead time for interventions by anticipating rather than simply reacting to outbreaks;
- Improve efficiency in the use of limited health and DRRM resources by focusing on forecasted high-risk barangays;
- Strengthen compliance and accountability through automated, timely, and complete reporting and transparent risk information; and

- Align health action with broader resilience and smart city goals, integrating dengue risk with climate, flood, and infrastructure planning.

In summary, adopting the recommended package of measures would enable Baguio City to turn routine health data into actionable foresight, ensuring that each public health peso is spent where and when it matters most. This shift from descriptive to predictive governance in dengue control can also serve as a model for other health and risk domains, reinforcing Baguio’s position as a leading resilient smart city in the Philippines.

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