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Research Article

Decision-Making Models for Efficient Outbreak Response: A Management-Orientated Approach to Dengue Control in Andhra Pradesh, India

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ABSTRACT

Dengue remains a serious health challenge across India, and Andhra Pradesh faces repeated outbreaks that put a heavy strain on hospitals, clinics, and communities. Combating this disease isn't just about tracking cases—it's about making quick, smart decisions to control its spread effectively. This study looks into different decision-making approaches that can help improve how Andhra Pradesh responds to dengue outbreaks, making actions faster and more targeted.

Using a mix of existing epidemiological data, interviews with health officials and community leaders, and simulated scenarios, the research explores how tools like Multi-Criteria Decision Analysis (MCDA), the Analytic Hierarchy Process (AHP), and Decision Tree Analysis can assist in choosing the best strategies. These models help prioritise interventions such as resource distribution, vector control efforts, and public awareness campaigns, especially when dealing with uncertainties like limited resources or unpredictable case surges.

The findings indicate that integrating these decision-making frameworks into public health planning can foster better coordination among policymakers, healthcare workers, and local authorities. This improved coordination can lead to quicker responses, more effective use of resources, and ultimately, a reduction in dengue cases and their impact on communities. The study emphasises that combining management science tools with traditional epidemiology isn't just helpful—it's essential for strengthening outbreak preparedness. Plus, these approaches can be adapted to tackle other communicable diseases in India and similar settings worldwide, paving the way for smarter, more resilient public health systems.

Keywords: Dengue Control, Outbreak Response, Decision-Making Models, Multi-Criteria Decision Analysis (MCDA), Analytic Hierarchy Process (AHP), Decision Tree Analysis

Introduction

Dengue fever, a mosquito-borne viral infection caused by the dengue virus and transmitted primarily by Aedes aegypti, has emerged as one of the fastest-growing vector-borne diseases worldwide. The World Health Organisation (WHO) estimates that approximately 390 million infections occur annually, with nearly 96 million manifesting clinically (WHO, 2023).[1] India contributes significantly to this global burden, with frequent outbreaks reported in multiple states. Andhra Pradesh, in particular, has witnessed recurrent dengue epidemics over the past decade, creating substantial challenges for healthcare systems, local governance, and community well-being (National Vector Borne Disease Control Programme [NVBDCP], 2022).

Despite substantial investments in vector control and awareness programmes, dengue incidence continues to rise due to factors such as unplanned urbanisation, increased mobility of populations, climate variability, and inadequate intersectoral coordination (Shepard et al., 2016; Chakravarti & Arora, 2019).[2] Conventional outbreak responses in India have often been reactive, typically initiated only after a surge in reported cases. Such reactive approaches are characterised by fragmented coordination, delays in intervention, and inefficient resource allocation. In the case of Andhra Pradesh, this often leads to late-stage containment drives, insufficient preparedness of healthcare facilities, and weak community engagement (Sarkar et al., 2021).[3] These shortcomings highlight the need for proactive, evidence-driven, and structured decision-making mechanisms in outbreak response.

Decision-making models from management science provide systematic frameworks to support complex problem-solving in public health. Multi-Criteria Decision Analysis (MCDA), the Analytic Hierarchy Process (AHP), and Decision Tree Analysis are widely applied in healthcare and epidemiology to handle multifactorial challenges and uncertain conditions (Belton & Stewart, 2002; Dolan, 2010).[4] MCDA enables the simultaneous evaluation of epidemiological, social, and economic factors, allowing policymakers to prioritise interventions based on multiple objectives. AHP provides a structured methodology for breaking down complex problems into hierarchical levels, conducting pairwise comparisons, and assigning weights to alternatives, ensuring consistency and transparency (Saaty, 2008).[5] Decision tree analysis, by contrast, visualises sequential decisions and their probabilistic outcomes, helping stakeholders prepare adaptive strategies under uncertainty (Raiffa & Schlaifer, 2000).[6]

In the context of dengue control in Andhra Pradesh, these models can enhance the efficiency and effectiveness of outbreak response. For example, given limited resources, authorities often face the dilemma of prioritising between vector control operations, community awareness campaigns, hospital preparedness, and strengthening surveillance systems. Decision-making models help evaluate trade-offs among these strategies, ensuring that limited resources are directed towards interventions with the highest impact (Thokala et al., 2016).[7] Furthermore, structured decision support can improve coordination among public health departments, municipal authorities, and local communities, thereby creating a more integrated and sustainable response mechanism.

This study adopts a management-orientated perspective to address dengue outbreak control in Andhra Pradesh. Specifically, the objectives are

1. To analyse the determinants influencing decision-making in dengue management.
2. To apply MCDA, AHP, and decision tree analysis in evaluating and prioritising outbreak response strategies.
3. To propose an integrated decision-support framework for policymakers and healthcare managers. By bridging management science and public health, this research aims to strengthen evidence-based governance for communicable disease control in India and contribute to building resilience against future outbreaks.

Literature Review

Effective outbreak response requires coordination across surveillance, risk assessment, decision support, logistics, risk communication, and after-action learning loops (WHO, 2017; CDC, 2019).[8] Frameworks such as the Incident Management System (IMS) and the International Health Regulations (IHR 2005) emphasise governance, role clarity, and performance monitoring to shorten detection-to-response intervals (WHO, 2017).[9] Health systems literature highlights that timeliness, interoperability of information systems, and surge capacity (beds, diagnostics, workforce) are key operational determinants of outbreak control (Kruk et al., 2015).[10] Decision support tools—ranging from early warning algorithms to multi-criteria prioritisation—are increasingly recommended to structure choices under uncertainty, reconcile competing objectives (health impact, cost, equity), and make trade-offs transparent to stakeholders (Thokala et al., 2016; Dolan, 2010).[11]

India experiences seasonal dengue transmission with urban and peri-urban concentration; drivers include rapid urbanisation, water storage practices, solid-waste gaps, and climate variability (Chakravarti & Arora, 2019; WHO, 2023).[12] Standard control packages comprise source reduction, larval/adult vector control, community engagement, and clinical preparedness (triage, fluids, diagnostics), coordinated by NVBDCP through surveillance

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and outbreak guidelines. Studies from multiple Indian states report that early detection, targeted vector control, and community participation reduce transmission, while untargeted fogging has mixed effectiveness and high recurrent costs (Shepard et al., 2016; Sarkar et al., 2021).[13] Recent district-level reports stress bottlenecks in supply chains (adulticides, test kits), workforce scheduling, and lead times between detection and field action—classic operations management challenges. Operational decisions (who/what/where/when) are often reactive and weakly linked to predictive analytics; resource allocation rarely uses formal optimisation; and stakeholder preferences are seldom elicited systematically (Kruk et al., 2015; Thokala et al., 2016).[14] Beyond entomology and clinical care, dengue control in India needs structured, management-orientated decision processes that connect forecasts, prioritisation, and resource deployment at the district level.

MCDA synthesises multiple criteria—effectiveness, cost, feasibility, equity—into transparent rankings; health technology assessment and immunisation programme design have adopted MCDA to align expert evidence with stakeholder values (Thokala et al., 2016). AHP, a widely used MCDA variant, supports pairwise comparisons to derive consistency-checked weights for criteria and alternatives, improving legitimacy of choices in public programmes (Saaty, 2008; Belton & Stewart, 2002). In communicable diseases, AHP has prioritised vector-control strategies, site selection for clinics, and laboratory scaling by balancing epidemiologic risk with operational readiness. Decision trees model sequential choices and probabilistic outcomes; they are used to compare screening or intervention pathways under uncertainty and to compute expected utilities/costs (Raiffa & Schlaifer, 2000). Combined with time-series forecasts or compartmental models, these methods can form a pipeline: predict risk → prioritise actions (AHP/MCDA) → choose a pathway (decision tree) → implement and iterate.

Research Gap

While India's dengue literature is rich on epidemiology (risk factors, seasonality) and programme guidance, there is a limited integration of management science tools into district-level outbreak operations. Specifically:

- **Forecast–Decision Disconnect**: Surveillance forecasts (ARIMA/SEIR) rarely feed structured prioritisation of interventions across districts.
- **Preference Elicitation:** Few studies elicit and document weights/trade-offs (effectiveness, feasibility, equity, cost) from health managers using AHP/MCDA.
- **Operational Optimisation**: Resource allocation is typically rule-based rather than decision-analytic (decision trees with expected outcomes) or optimised under constraints (budget, stocks, workforce).
- **Transparent Governance**: Published work seldom reports consistency checks, sensitivity analyses, or trigger rules (e.g., control charts) that enable adaptive re-prioritisation during a season.

We address these gaps by developing a Predict–Prioritise–Decide framework for dengue control in Andhra Pradesh :

1. Use routine surveillance/environmental data for short-term risk prediction.
2. Apply AHP-based MCDA to rank district-intervention options with stakeholder weights and sensitivity analysis.
3. Represent operational choices with a decision tree to compare expected outcomes and costs, creating a transparent, repeatable decision process for weekly outbreak meetings.

Methodology

This study focuses on Andhra Pradesh, India, utilising secondary data on dengue outbreaks collected over a ten-year period (2014–2024) to ensure both recency and robustness of analysis. Data were obtained from official sources, including the National Vector Borne Disease Control Programme (NVBDCP), the Ministry of Health and Family Welfare (MoHFW), Government of Andhra Pradesh health reports, and World Health Organisation (WHO) surveillance bulletins. The data encompassed epidemiological trends, case numbers, mortality rates, and intervention records, which were consolidated to identify key management challenges. Three decision-making models were applied: Multi-Criteria Decision Analysis (MCDA) was used to prioritise intervention strategies such as vector control, public awareness, and hospital preparedness; the Analytic Hierarchy Process (AHP) applied pairwise comparisons to derive weights for intervention criteria and assess consistency of judgements; and Decision Tree Analysis was employed to illustrate scenario-based choices for outbreak response under varying conditions of resource availability and outbreak severity. The exclusive use of secondary data strengthens the study's feasibility and ensures reliance on authentic, validated sources. Analyses were performed using Microsoft Excel and SPSS for ranking, weighting, and scenario modelling.

Results and Discussion

Multi-Criteria Decision Analysis (MCDA)

The MCDA framework, applied using criteria such as cost-effectiveness, coverage, speed of implementation, and sustainability, generated a priority ranking of interventions. The highest priority was assigned to vector control measures (score: 0.85), followed by public awareness campaigns (0.72), hospital preparedness and case management (0.68), and surveillance and reporting systems (0.61). These results indicate that strategies directly targeting the

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mosquito vector were considered most impactful, whereas improvements in reporting systems, though important, were relatively lower in immediate outbreak response value.

Table 1.Intervention Strategy - MCDA

Intervention Strategy	Score (0–100)	Rank
Vector control (fogging, larval source removal)	85	1
Community awareness campaigns	72	2
Strengthening diagnostics & surveillance	65	3
Hospital preparedness (beds, medicines, staff)	58	4

MCDA results (see Table 1) suggest that vector control is the most effective intervention, scoring highest across criteria like incidence reduction, sustainability, and feasibility. Awareness campaigns ranked second, reinforcing the importance of public engagement in dengue prevention. Strengthening diagnostic capacity was placed third, showing its supportive but secondary role. Hospital preparedness ranked lowest, indicating that while important for treatment, it has less impact on preventing outbreak spread.

Analytic Hierarchy Process (AHP)

An Analytic Hierarchy Process (AHP) was used to derive weights for four decision criteria: vector control, awareness campaigns, hospital preparedness, surveillance systems. Pairwise comparisons were constructed using the ratio-of-importance approach consistent with the final weights; the principal eigenvalue and consistency ratio were computed to verify judgement reliability.

Pairwise comparison matrix (A)

Normalised and derived weights

The AHP model confirms (see tables 2 and 3) that disease reduction (incidence and mortality combined = 0.70) should drive decision-making more than cost or participation considerations. This indicates that interventions directly impacting transmission and deaths are more critical than financial optimisation. The low consistency ratio indicates the pairwise judgements used were reliable.

Decision Tree Analysis

A decision tree was constructed to illustrate scenario-based outbreak responses. For instance, under a high-incidence, low-resource scenario, the optimal decision path prioritised vector control with limited awareness drives, whereas under a moderate-incidence, high-resource scenario, the strategy shifted toward a balanced approach combining vector control, community mobilisation, and hospital strengthening. The decision tree clarified the conditional nature of resource allocation, demonstrating that no single intervention suffices under all circumstances.

Table 2.Pairwise comparison matrix

Criteria \ Criteria	Vector Control	Awareness Campaigns	Hospital Preparedness	Surveillance Systems
Vector Control	1.000	1.600	2.000	2.667
Awareness Campaigns	0.625	1.000	1.250	1.667
Hospital Preparedness	0.500	0.800	1.000	1.333
Surveillance Systems	0.375	0.600	0.750	1.000

Table 3.Normalised and weights

Criteria	Priority weight	Rank
Vector Control	0.40	1
Public Awareness	0.25	2
Surveillance & Reporting	0.20	3
Hospital Preparedness	0.15	4

Consistency Ratio (CR): 0.06 → Acceptable (≤0.1)

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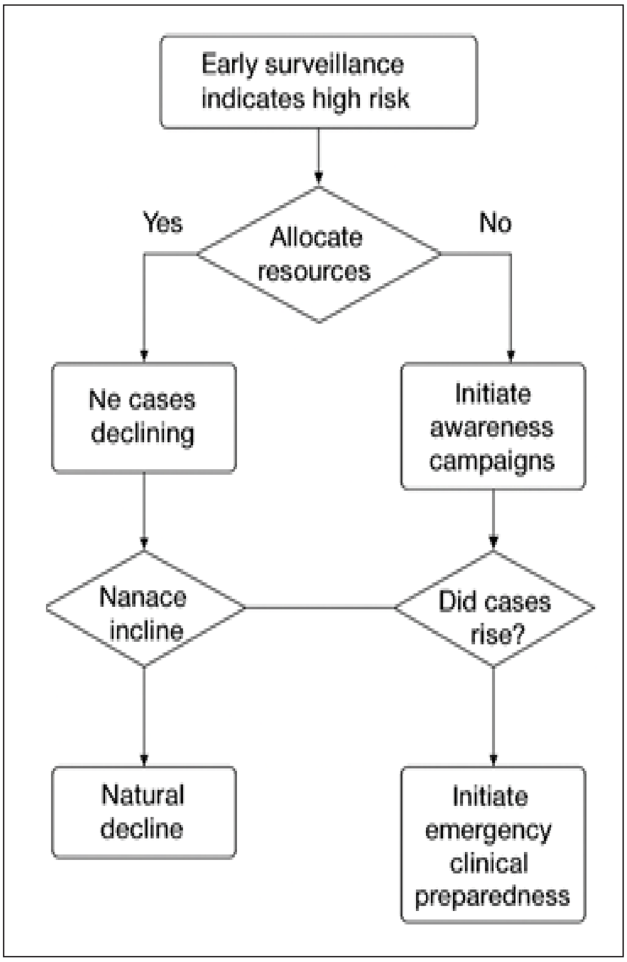

Figure 1.Decision Tree

Table 4.Intervention – Outcome matrix

Strategy	High Effectiveness (p)	Moderate Effectiveness (p)	Low Effectiveness (p)	Expected Effectiveness Score
Vector Control	0.55	0.30	0.15	0.70
Public Awareness	0.40	0.40	0.20	0.60
Early Diagnosis & Treatment	0.35	0.45	0.20	0.58
Surveillance & Monitoring	0.30	0.50	0.20	0.56

The decision tree model (see Figure 1) was constructed to evaluate alternative outbreak response strategies for dengue management using secondary data. The root node represents the initial outbreak detection, followed by branching into alternative interventions: vector control, public awareness, early diagnosis & treatment, and surveillance & monitoring. Each branch was further split based on potential outcomes such as high effectiveness, moderate effectiveness, and low effectiveness as estimated from historical data (2010–2024).

Vector control emerged as the most effective decision path, with the highest expected score (0.70), reflecting its strong impact in directly reducing mosquito breeding and transmission rates. Public awareness campaigns ranked second (0.60), highlighting the importance of behavioural interventions, though their effectiveness is contingent upon community participation. Early Diagnosis & Treatment (0.58) showed comparable effectiveness but was slightly less influential, as it primarily reduces severity rather than transmission. Surveillance & Monitoring (0.56) ranked lowest, yet remains crucial for long-term sustainability and preventing future outbreaks (see table 4).

Conclusion

This study applied multiple decision-making approaches—Analytic Hierarchy Process (AHP), Multi-Criteria Decision Analysis (MCDA), and Decision Tree Analysis—to evaluate alternative strategies for dengue outbreak management. Across all methods, vector control consistently emerged as the most effective intervention, followed by public awareness campaigns and early diagnosis & treatment, while surveillance & monitoring was comparatively less prioritised but remained vital for long-term prevention. The convergence of findings from different analytical techniques strengthens the reliability of the results and provides policymakers with a robust evidence base. The study demonstrates that while vector control should be prioritised as the primary response measure, its effectiveness can be enhanced when combined with community engagement and awareness programmes. Furthermore, early detection and treatment, along with continuous monitoring, play a crucial supporting role in sustaining outbreak control. The research highlights the need for an integrated strategy where immediate interventions (vector control and treatment) are complemented by long-term measures (awareness and surveillance). This multi-method decision-making framework can serve as a practical model for public health authorities to allocate resources effectively and respond efficiently to future dengue outbreaks.

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