e-ISSN:2582-7219

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH IN SCIENCE, ENGINEERING AND TECHNOLOGY

Volume 5, Issue 11, November 2022

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 7.54

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

| ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 7.54| Monthly, Peer Reviewed & Referred Journal|

| Volume 5, Issue 11, November 2022 |

| DOI: 10.15680/IJMRSET.2022.0511017 |

Programmatic Design of Integrated Disease Surveillance Platforms: A Public Health Project Management Perspective

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ABSTRACT: Integrated Disease Surveillance Platforms (IDSPs) are increasingly positioned as national and sub-national public health "mission systems," expected to convert heterogeneous signals - clinical, laboratory, environmental, pharmacy, mobility, and community reporting - into timely, trustworthy situational awareness. Yet, the majority of surveillance modernization initiatives fail to deliver lasting impact because they are treated as technology installations rather than complex, multi-stakeholder programs requiring disciplined governance, benefits realization, and sustained operational ownership.

This paper presents a programmatic design framework for Integrated Disease Surveillance Platforms grounded in public health informatics and project/program management principles. We propose an end-to-end reference model spanning surveillance objectives, data pipelines, interoperability, analytics, workforce operations, governance, risk controls, and performance measurement. A program-oriented implementation roadmap is introduced with phase gates, artifacts, and decision rights aligned to a multi-agency operating model.

Using a synthetic multi-region evaluation dataset, we quantify improvements in timeliness, completeness, and alert precision under progressive integration and governance maturity levels. The findings support the thesis that sustained surveillance performance is primarily a function of program governance, operating model clarity, and data quality management - enabled by technology, but not determined by it.

KEYWORDS: integrated disease surveillance, public health informatics, program management, governance, interoperability, data quality, outbreak detection, benefits realization, risk management

I. INTRODUCTION

Public health surveillance has expanded beyond conventional notifiable disease reporting. Contemporary surveillance must incorporate near-real-time clinical encounters, laboratory results, syndromic signals, wastewater and environmental monitoring, genomic sequencing, pharmacy and OTC purchase patterns, and community-reported symptoms, while maintaining privacy and policy compliance.

However, integrated surveillance remains operationally fragile: siloed systems, inconsistent reporting, fragmented governance, unclear ownership, and uneven workforce capacity routinely degrade platform reliability. From a program management perspective, an Integrated Disease Surveillance Platform is a sustained capability that must evolve across years, not a single project deliverable.

This paper addresses the question: How can public health agencies design and deliver integrated disease surveillance platforms as programs - ensuring measurable outcomes, operational sustainability, and trusted decision-making?

II. PROBLEM STATEMENT AND OBJECTIVES

2.1 Core Problem

IDSP modernization often fails due to (i) misalignment between objectives and measures ("more data" rather than "better decisions"), (ii) weak interoperability governance and inconsistent message quality, (iii) unclear operating model and escalation paths, (iv) under-resourced data quality operations, and (v) project drift driven by scope creep and vendor-led architecture without benefits accountability.

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2.2 Research Objectives

This study proposes: (1) a programmatic design framework for integrated surveillance platforms; (2) a reference architecture with governance and operational controls; (3) a phase-gated implementation roadmap with deliverables and decision rights; (4) a performance measurement system for timeliness, completeness, quality, and alert utility; and (5) an illustrative multi-region evaluation demonstrating how governance maturity improves surveillance outcomes.

III. CONCEPTUAL FOUNDATIONS

3.1 Integrated Surveillance as a Capability System

An IDSP is a "capability system" that includes data sources, an interoperability layer, analytics and detection services, operations and response workflows, governance and security controls, and continuous improvement routines (metrics, audits, and releases). Programs that frame surveillance as a capability system emphasize institutional ownership, operational accountability, and long-term sustainability rather than short-term deployment milestones.

3.2 Program Management Lens

Program management is appropriate because surveillance integration spans multiple projects: interoperability onboarding; data-lake/warehouse modernization; analytics development and validation; case management and response workflow implementation; workforce training and change adoption; and legal/privacy modernization and data-sharing agreements.

IV. PROGRAMMATIC DESIGN FRAMEWORK FOR IDSPS

The framework below defines the core design dimensions and corresponding program controls. It is intentionally operational: it can be used to structure charters, backlogs, phase gates, and governance artifacts.

Dimension	Program Design Question	Typical Failure Mode	Program Control
Surveillance Objectives	What decisions must be improved?	Collecting data without outcomes	Benefits map + KPI tree
Stakeholder Operating Model	Who owns what across agencies?	Ambiguity and slow escalation	RACI + decision rights
Data Integration	How are sources onboarded and validated?	Inconsistent feeds, silent failures	Data contracts + SLAs
Governance & Privacy	How is access justified and audited?	Over/under-sharing; compliance risk	DPIA, role-based access, logs
Analytics & Alerting	How are alerts tuned and validated?	Alert fatigue; low trust	Model governance + calibration
Incident & Response Workflow	How do alerts translate to action?	Dashboards without response	Standardized playbooks
Quality & Reliability	How is the platform monitored daily?	Data drift; outages discovered late	SLOs + monitoring + runbooks
Workforce Capacity	Who runs the platform sustainably?	Tooling without capability	Training + staffing model
Change & Release	How do updates happen safely?	Uncontrolled changes	CAB + versioning + rollback
Sustainability	How does capability evolve yearly?	One-time funding cliffs	Multi-year roadmap + OPEX plan

Table 1. Programmatic Design Dimensions (IDSP)

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V. REFERENCE ARCHITECTURE

Integrated surveillance requires a layered architecture that supports secure onboarding, canonical interpretation, analytics, operational workflows, and governance services.

Figure 1. Integrated Disease Surveillance Reference Architecture (conceptual)

[Data Sources] →	[Ingestion & Validation] →	[Canonical Data Model] →	[Analytics & Detection] →	[Ops & Response]
EHR/ADT Labs/LOINC Wastewater Pharmacy Community	HL7/FHIR, APIs Schema checks, Dedup, PII controls Data contracts/SLA	Patient/Case, Lab, Location, Disease ontology	Rules, anomaly detection, nowcast dashboards	Triage queues, investigations, reporting
	↓	↓	↓	
	[Governance & Security] Access control, audit Privacy reviews, DUA	[Data Quality Ops] Completeness, timeliness drift, incident mgmt	[Performance Mgmt] KPIs, benefits, program reporting	

Layer	Component	Primary Purpose	Key Deliverable
Sources	EHR/Lab/Wastewater/Pharmacy	Capture multi-signal indicators	Source inventory + onboarding plan
Ingestion	API gateway / HL7/FHIR adapters	Secure, standardized intake	Data contracts + validation rules
Data mgmt	Canonical model + metadata catalog	Consistent interpretation	Canonical schema + data dictionary
Storage	Lakehouse / warehouse	Scalable, auditable history	Retention policy + partition design
Analytics	Detection rules + models	Identify signals & outbreaks	Alert definition catalog
Operations	Case management workflows	Turn alerts into action	Playbooks + SLA for triage
Governance	Privacy, security, oversight	Lawful, trusted operations	Data-sharing agreements + audits
Reliability	Observability + SLO	Continuous availability & quality	Runbooks + incident procedures

Table 2. Architecture Components and Purpose

VI. PROGRAM GOVERNANCE MODEL

Surveillance platforms require an explicit governance operating model to sustain multi-agency alignment, reduce escalation friction, and institutionalize decision-making.

Governance Body	Participants	Decision Scope	Cadence	Key Outputs
Executive Steering Committee	Health leadership, legal, finance	Funding, scope, priorities	Monthly	Roadmap approvals
Data Governance Council	CDO, epidemiology lead, labs, IT	Standards, access, sharing	Bi-weekly	Data policies, DUA templates

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Clinical/Lab Integration Board	Hospitals, labs, interoperability team	Onboarding, mapping, quality	Weekly	Feed approvals, remediation plans
Analytics Governance Board	Epidemiologists, data science, ethics	Model/rule approval, bias checks	Monthly	Alert tuning, validation reports
Operations Council	Field ops, comms, incident mgmt	Response workflows, triage rules	Weekly	Playbooks, staffing plans
Change Advisory Board (CAB)	IT ops, security, platform team	Releases, changes, rollback	Weekly	Release calendar, approvals

Table 3. Governance Structure (Multi-Agency IDSP)

Activity	Epidemiology	Lab	Platform Ops	Data Governance	Field Response	Legal/Privacy
Define alert criteria	A/R	C	C	C	C	C
Validate data feed quality	C	A/R	R	C	C	C
Approve analytics update	A/R	C	C	C	C	C
Triage alerts daily	A/R	C	R	C	R	C
Case investigation	A	C	C	C	R	C
Public reporting	A/R	C	C	C	C	A/C
Audit access logs	C	C	R	A/R	C	A/R

Table 4. RACI Example for Alert-to-Action

VII. IMPLEMENTATION ROADMAP WITH PHASE GATES

Phase	Primary Goal	Key Deliverables	Gate Criteria
Discover	Agree on outcomes	Benefits map, source inventory, stakeholder map	Clear KPI tree + sponsor sign-off
Design	Define standards & operating model	Canonical model, governance charters, security model	Signed DUA templates + RACI
Build & Integrate	Deliver platform increments	Ingestion pipelines, DQ monitors, dashboards	SLOs met + playbooks ready
Operate & Improve	Stabilize and tune	Incident process, alert tuning cycles, training	Sustained KPI improvement
Scale & Sustain	Expand sources/regions	Partner onboarding factory, OPEX model	Multi-year funding + adoption evidence

Table 5. Phase Outputs (Practical Deliverables)

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VIII. MEASUREMENT FRAMEWORK

Category	Metric	Definition	Target Example
Timeliness	Median reporting latency	Event → platform ingestion	≤ 24 hours (notifiable); ≤ 2 hours (syndromic)
Completeness	Field completeness score	Required fields present (%)	≥ 95%
Accuracy	Coding validity	LOINC/ICD correctness (%)	≥ 98%
Reliability	Platform availability	Uptime for ingestion/analytics	≥ 99.5%
Alert Utility	Precision / PPV	True signals / all alerts	≥ 0.60 (initial), improve quarterly
Operational Response	Time to triage	Alert arrival → triage action	≤ 4 hours
Equity	Coverage parity index	Coverage across demographics	≥ 0.90 parity

Table 6. Surveillance Performance Indicators (KPI Tree)

IX. SYNTHETIC EVALUATION (ILLUSTRATIVE DATASET AND RESULTS)

9.1 Evaluation Setup

A 12-month rollout is simulated across four regions with three maturity stages: Stage A (fragmented feeds, minimal governance), Stage B (integration with data contracts and monitoring), and Stage C (mature governance with tuned alerting and operational playbooks).

Region	Population (M)	Hospitals	Labs	Wastewater Sites	Reporting Feeds
R1	3.2	28	12	18	44
R2	2.4	20	9	12	31
R3	4.1	36	15	22	58
R4	1.8	14	6	9	22

Table 7. Synthetic Regional Baseline (Population & Facilities)

Region	Stage A (hrs)	Stage B (hrs)	Stage C (hrs)	% Improvement (A→C)
R1	54	26	14	74.10%
R2	62	30	16	74.20%
R3	48	24	12	75.00%
R4	70	34	18	74.30%

Table 8. Timeliness Improvement by Program Maturity (Median Latency)

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Region	Stage A (%)	Stage B (%)	Stage C (%)
R1	83	93.5	97.2
R2	79.4	92.1	96.4
R3	85.2	94	97.8
R4	77.8	91.6	95.9

Table 9. Completeness Score Improvement (Required Fields Present)

Stage	Alerts per Week	True Signals per Week	Precision (PPV)	Notes
A	220	62	0.28	Alert fatigue dominates
B	160	70	0.44	Data quality + basic rules
C	115	74	0.64	Calibration + governance

Table 10. Alert Utility (Precision / PPV) and Alert Volume

Stage	Incidents (per 100 feeds/month)	Mean Time to Detect (hrs)	Mean Time to Resolve (hrs)
A	18.5	72	120
B	9.2	14	38
C	4.6	4	16

Table 11. Data Quality Incident Rate and Response

9.2 Interpretation

The synthetic results highlight that governance and observability reduce "silent failure windows," frequently generating more reliable surveillance than adding additional analytics alone. As maturity improves, operational confidence increases, alert fatigue declines, and triage performance becomes sustainable.

X. RISK MANAGEMENT AND CONTROLS

Risk	Likelihood	Impact	Mitigation	Owner
Data sharing delays (DUA)	High	High	Standard DUA templates + early legal engagement	Data Governance
Feed quality variance	High	High	Data contracts + validation + remediation	Integration Board

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Alert fatigue	Medium	High	Calibration cycles + threshold governance	Analytics Board
Privacy breach	Low	Very High	RBAC, audit logs, DPIA, encryption	Security/Privacy
Workforce shortage	Medium	High	Training + staffing model + SOPs	Ops Council
Vendor lock-in	Medium	Medium	Open standards + portability strategy	Platform Lead

Table 12. IDSP Program Risk Register (High-Impact Risks)

XI. WORKFORCE AND OPERATING MODEL

Function	Role	FTE Range	Primary Responsibilities
Surveillance Ops	Surveillance duty officer	2–4	Triage, escalation, coordination
Epidemiology	Senior epidemiologist	2–5	Signal interpretation, response
Data Quality	Data steward / DQ analyst	2–4	Monitoring, anomalies, remediation
Platform Ops	SRE / reliability engineer	2–4	Uptime, incident management
Integration	Interoperability engineer	2–6	Onboarding, HL7/FHIR mapping
Analytics	Data scientist/analyst	2–6	Detection tuning, reporting
Governance	Privacy & compliance lead	1–2	DPIA, audits, access controls

Table 13. Minimum Sustainable Operating Team (Indicative)

XII. FINANCIAL MODEL AND BENEFITS REALIZATION

Cost Category	Examples	Type
Data onboarding	Connectors, mapping, validation	CAPEX
Platform build	Storage, compute, security	CAPEX
Operations	Monitoring, duty coverage, support	OPEX
Governance	Legal/privacy, audits, training	OPEX
Continuous improvement	Enhancements, new signals	Mixed

Table 14. Cost Categories (CAPEX/OPEX)

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Benefit	Mechanism	Metric	Example Outcome
Faster detection	Reduced latency + integrated signals	Median latency	54h → 14h
Better signal trust	Governance + calibration	Precision (PPV)	0.28 → 0.64
Reduced investigation waste	Fewer false positives	Cases per true event	Down 35–50%
Improved coverage equity	Partner onboarding factory	Parity index	#ERROR!

Table 15. Benefits Map (Outcome-Oriented)

Discussion

The synthetic evaluation suggests a consistent pattern: performance improvements correlate more strongly with governance and operations maturity than with additional data sources alone. While expanded coverage increases detection potential, it also increases quality variance and operational noise unless the program institutionalizes onboarding, validation, monitoring, and change control.

Alert precision functions as a proxy for trust. Low precision drives alert fatigue, causing frontline triage teams to disengage and reducing effective surveillance sensitivity. Programs that establish analytics governance - clear calibration rules, drift monitoring, and ethical review - achieve higher adoption and faster action.

XIII. PRACTICAL RECOMMENDATIONS (PROGRAM PLAYBOOK)

#	Control	Why it matters
1	Benefits map + KPI tree	Prevents “data-first” drift
2	Data contracts per source	Enforces consistency
3	Onboarding factory	Scales integration systematically
4	DQ dashboards + incident SLAs	Stops silent failures
5	Governance charters + decision rights	Speeds resolution
6	Alert catalog + tuning cadence	Reduces fatigue
7	Playbooks (alert→action)	Converts insight to response
8	Access audits and DPIA	Maintains trust and compliance
9	Change advisory board	Safer releases
10	Training + staffing plan	Sustains capability

Table 16. Ten Actionable Program Controls

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XIV. CONCLUSION

Integrated disease surveillance platforms must be designed and delivered as programs, not isolated projects. The essential differentiator is not the presence of advanced analytics, but the existence of a stable operating model - governance, data stewardship, reliability engineering, and continuous improvement - capable of sustaining trust, performance, and lawful data use.

A programmatic design approach provides the institutional infrastructure that allows technology to become an enduring public health capability.

Appendix A: Canonical Surveillance Data Elements (Example)

Domain	Core Elements
Person	age band, sex, residence region, risk group flags
Event	symptom onset date, encounter date, reporting date
Clinical	syndrome classification, severity, disposition
Lab	test type (LOINC), result, specimen date
Location	facility ID, geocode, wastewater site
Case/Investigation	case status, investigator, actions
Policy	reporting jurisdiction, legal basis, consent constraints

Table A1. Canonical Elements (Illustrative)

Appendix B: Sample Data Quality Rules (Examples)

Rule	Description	Severity
Date integrity	onset ≤ encounter ≤ report	High
Code validity	ICD/LOINC in approved lists	High
Required fields	missing threshold > 5%	Medium
Duplicates	probabilistic match above threshold	Medium
Drift	sudden distribution shift	High

Table B1. Data Validation Rules

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Data and Ethics Note

All quantitative results in this manuscript are synthetic and illustrative, designed to demonstrate how a programmatic approach can be evaluated. For submission or operational use, values should be replaced with analyses based on authoritative datasets and documented methods.

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Impact Factor
7.54

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