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From Animal Infection to Human Risk: A One Health Decision Architecture for Translating Veterinary Detection Into Exposure Assessment, Risk Escalation, Cross-Sector Communication, Public-Health Action, and Reassessment

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ABSTRACT

Veterinary detection of a zoonotic pathogen is often treated as an implicit indicator of human risk, yet the inferential distance between an infected animal and a consequential human-health threat is substantial. This article develops an original non-empirical One Health decision architecture for translating veterinary detection into exposure assessment, risk escalation, communication, action, and reassessment without assuming that detection alone determines public-health significance. The analysis separates pathogen characteristics, animal-host and infection context, human exposure pathways, exposure intensity and duration, human susceptibility, environmental persistence, and evidential confidence. These domains are treated as interacting but non-interchangeable determinants of actionability. The architecture further distinguishes biological plausibility from demonstrated exposure and transmission, and it preserves uncertainty when data are sparse, temporally unstable, species-specific, or derived from experimental models. Recent H5N1 infection in dairy cattle and exposed workers provides a high-resolution stress test, while broader zoonotic surveillance, risk-assessment, communication, governance, and evaluation literature supplies the general One Health foundation. The central contribution is a proposed conditional decision structure in which veterinary signals are progressively contextualized rather than converted directly into fixed risk categories. The approach is intended to support more disciplined cross-sector reasoning and clearer reassessment triggers, not to provide a validated scoring system or universal escalation threshold. Prospective testing, jurisdiction-specific adaptation, and external validation remain necessary before effectiveness or implementation claims can be made.

Keywords: One Health, Zoonotic spillover, Veterinary surveillance, Exposure assessment, Risk escalation, Cross-sector communication

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Introduction

Veterinary surveillance can reveal a zoonotic hazard before human disease is recognized, but animal infection is not equivalent to human risk. Spillover requires multiple ecological and biological barriers, including pathogen release, survival outside the reservoir, a credible route of exposure, and susceptibility of the recipient host [1]. One Health extends the relevant decision space across human, animal, and ecosystem domains, making cross-sector integration a defining requirement rather than an optional reporting layer [2]. Yet recent wildlife-zoonosis

research shows that environmental, social, and participatory dimensions remain incompletely integrated in many studies, illustrating the gap between invoking One Health and operationalizing it [3].

The panzootic expansion of highly pathogenic avian influenza A(H5N1) clade 2.3.4.4b, including incursions into mammalian hosts and dairy cattle, demonstrates how quickly the significance of a veterinary signal can change when host range, exposure patterns, and surveillance demands shift [4]. This article therefore asks a narrower decision question: what information must be added to an animal detection before public-health escalation is justified? It argues that veterinary detection should initiate, not complete, risk inference. The proposed architecture separates hazard characteristics, animal context, human exposure, susceptibility, persistence, evidential confidence, communication, response, and reassessment while preserving uncertainty and jurisdictional boundaries.

Veterinary detection as the starting state

A veterinary detection establishes that a pathogen or pathogen-associated signal has been identified in an animal, specimen, herd, flock, wildlife population, or production environment. It does not, by itself, establish that humans have been exposed, that viable pathogen reached a relevant portal of entry, or that onward transmission is plausible. This distinction follows directly from the staged nature of spillover, in which reservoir infection is only one prerequisite among several [1]. The first decision task is therefore contextualization: what was detected, in which host, from which specimen, under what clinical and epidemiological circumstances, and with what uncertainty?

The urgency of that contextualization can change rapidly. H5N1 clade 2.3.4.4b illustrates how an animal-health event can acquire different public-health meaning when the host range expands and infections occur in production systems that create repeated human contact [4]. The proposed architecture consequently treats veterinary detection as a starting state with an explicit evidence envelope rather than a binary trigger. A signal may justify intensified characterization or exposure investigation while remaining insufficient for higher-order public-health action. This prevents both premature escalation from an isolated finding and delayed escalation when additional risk-relevant context is accumulating.

Pathogen characteristics

Pathogen characteristics determine what an animal detection could plausibly mean, but no single characteristic should substitute for the others. Experimental work with bovine-origin H5N1 demonstrates this separation: substantial pathogenicity and replication in mammalian models can coexist with inefficient respiratory-droplet transmission in ferrets [5]. Virulence, tissue tropism, replication competence, and transmissibility therefore represent distinct evidential dimensions. A pathogen that produces severe disease in one model should not automatically be classified as efficiently transmissible among humans.

Molecular findings require the same restraint. A hemagglutinin mutation in bovine H5N1 can switch receptor specificity toward human-type receptors, making sequence and receptor-binding information relevant to reassessment [6]. However, receptor preference is only one determinant of successful transmission and cannot establish population-level spread. Likewise, characterization of a human isolate from the cattle-associated episode revealed consequential phenotypes in animal models [7]. Such evidence can update the risk interpretation after cross-species infection has occurred, but it does not prove sustained human-to-human transmission. The decision architecture therefore treats pathogen phenotype as dynamic evidence: it can strengthen or weaken concern, yet must remain bounded by model validity, isolate representativeness, and the gap between laboratory phenotype and field transmission.

Animal host and infection context

The same pathogen can carry different implications depending on the infected animal host, tissue compartment, clinical state, and production context. Experimental bovine H5N1 work shows that host biology and tissue tropism materially shape the observed phenotype [5]. Accordingly, an animal-positive result should not be interpreted independently of species, age or production class where relevant, specimen source, clinical status, and whether the finding represents an isolated host, a clustered event, or a broader change in host range.

The contemporary H5N1 panzootic reinforces this contextual requirement because its significance has changed as the virus has been detected across avian and mammalian hosts and entered dairy production systems [4]. That evolution does not imply that every mammalian infection carries equal human-health risk. Instead, animal context

modifies the opportunity for shedding, environmental contamination, repeated occupational contact, and further adaptation. In the proposed architecture, these factors remain analytically separate from pathogen characteristics: a high-consequence pathogen in a low-contact wildlife setting may demand a different response from the same pathogen in a production system with frequent close human interaction. Numerical transfer between species or settings is therefore avoided unless directly supported.

Human exposure pathways

Human risk becomes more actionable when a plausible animal-to-human exposure pathway is identified. A laboratory-confirmed H5N1 infection in a Texas dairy worker with conjunctivitis established that occupational contact with infected cattle could coincide with human infection and that ocular exposure cannot be ignored in a respiratory-dominant risk model [8]. Subsequent Michigan cases added more granular exposure information, including close contact with dairy cattle, variable personal protective equipment use, and a reported milk splash to the eye [9]. These observations do not quantify route-specific transmission probabilities, but they show why exposure history must travel with the veterinary signal.

Environmental contamination can create additional pathways. Experimental work demonstrated persistence of infectious H5N1 in unpasteurized milk on milking-unit surfaces under tested conditions [10]. That finding supports the plausibility of exposure beyond direct animal contact, while stopping short of showing that fomite transmission caused human infection. The architecture therefore distinguishes direct animal contact, contaminated biological material, aerosol or droplet exposure, ocular or mucosal contact, and contaminated environmental surfaces when evidence supports them. Route plausibility increases interpretive specificity, but it does not become proof of transmission without compatible epidemiological evidence.

Exposure intensity and duration

Exposure should not be reduced to a binary classification. The frequency and duration of contact, proximity to infectious material, portal of entry, use of protective barriers, and repetition across work tasks can materially alter the meaning of the same hazard. The Michigan dairy-worker investigations illustrate why route and protective-equipment details are decision relevant: exposure histories contained information that a simple “occupationally exposed” label would erase [9]. The evidence does not justify assigning numerical weights to those features, but it supports preserving them as separate descriptors.

Time also matters because infectious material may persist after the initiating animal contact. Viable H5N1 was recovered from experimentally contaminated milking surfaces over time under laboratory conditions [10]. This establishes a persistence dimension without defining a field dose-response relation or a universal duration threshold. The proposed architecture therefore represents intensity and duration as modifiers of exposure confidence rather than as a score. Repeated high-contact tasks, direct contact with infectious secretions, or prolonged access to contaminated environments may justify more urgent investigation, whereas uncertain, brief, or indirect contact may justify observation and verification. Any such distinction remains conditional on pathogen, setting, barrier use, and data quality.

Human susceptibility

Exposure does not translate uniformly into infection or severe disease. Experimental work with a cattle-associated H5N1 virus shows that ocular tissues can support infection and replication, making portal-specific susceptibility biologically relevant [11]. This finding strengthens the rationale for distinguishing ocular, respiratory, oral, and other plausible routes when interpreting exposure, but it does not define a human dose threshold or population-level attack rate.

Host factors further modify risk. Influenza susceptibility and severity vary with prior immunity, age, underlying health, host biology, and interacting viral or environmental determinants [12]. Clinical experience with novel avian influenza viruses also shows that infection and disease severity are not interchangeable outcomes; clinical patterns vary by subtype, exposure context, and host characteristics [13]. The architecture therefore separates susceptibility to infection from vulnerability to severe outcome. Neither dimension is treated as deterministic, and neither is allowed to compensate automatically for weak exposure evidence.

Table 1 presents separate effects of exposure route, infection susceptibility, and severe-outcome vulnerability on human-risk interpretation.

Table 1. Separate effects of exposure route, infection susceptibility, and severe-outcome vulnerability on human-risk interpretation

Susceptibility dimension	Route or host basis	Risk inference altered	Current handling of the signal	Question left open and evidence needed
Route-concordant susceptibility	**Context:** Portal of entry; barrier use **Observed:** Compatible exposure history; route-specific findings	Exposure is more biologically coherent when portal and tissue tropism align	Increase attention to route-specific investigation	**Unresolved:** Does not establish dose or transmission probability **Needed next:** Reassess if clinical or virological evidence emerges
Host-vulnerability modifier	**Context:** Prior immunity; age; health status **Observed:** Documented host characteristics	Equal exposure may not imply equal infection risk	Preserve individualized follow-up intensity	**Unresolved:** Relative contribution may be uncertain **Needed next:** Update when host or immunity information changes
Severity-vulnerability pattern	**Context:** Comorbidity; host response; viral subtype **Observed:** Clinical risk profile	Infection probability and severe-disease probability remain separate	Separate prevention of infection from consequence management	**Unresolved:** Severity cannot be inferred from exposure alone **Needed next:** Reassess if symptoms or disease markers develop
Uncharacterized susceptibility	**Context:** Unknown immunity; uncertain portal **Observed:** Incomplete history or sparse evidence	Missing host or route information limits confidence	Avoid false reassurance or automatic escalation	**Unresolved:** Evidence gap is itself decision relevant **Needed next:** Prioritize information acquisition

Environmental persistence

Environmental persistence determines how long and where an animal-associated hazard may remain available for human contact. In dairy-relevant experiments, infectious H5N1 persisted in unpasteurized milk deposited on milking-unit surfaces under defined laboratory conditions [10]. The correct inference is limited but important: contaminated matrices and surfaces can extend the plausible exposure window. Persistence alone does not establish that a human received an infectious dose, that a specific route caused infection, or that laboratory survival times reproduce farm conditions.

This boundary is consistent with the broader spillover pathway, in which environmental survival lies between pathogen release and successful recipient-host exposure [1]. Persistence should therefore be represented as an exposure modifier rather than a surrogate for transmission. Temperature, matrix composition, cleaning, ultraviolet exposure, surface material, ventilation, and other environmental conditions may alter viability, but only factors directly supported in the relevant setting should enter a decision. In the proposed architecture, environmental evidence can strengthen concern when it aligns with a plausible human pathway and compatible animal shedding. When it is isolated from exposure evidence, it should prompt targeted investigation rather than automatic escalation. The distinction protects against both underestimating persistent hazards and overstating laboratory viability as demonstrated human risk.

Evidence thresholds for risk escalation

Risk escalation requires evidence convergence, not a single universal trigger. Global work on prioritizing endemic zoonoses for domestic-animal surveillance demonstrates that public-health relevance can be structured across multiple criteria rather than inferred from one disease attribute [14]. Applied to an emergent animal detection, the relevant question is not simply whether the pathogen is present, but whether pathogen characteristics, animal context, human exposure, susceptibility, environmental persistence, and evidence quality jointly justify a different response state.

Method choice also depends on available data, analytic capability, time pressure, and uncertainty. A One Health decision-support tool for risk assessors shows the value of matching the assessment approach to those constraints rather than treating all evidence as equally interpretable [15]. The proposed architecture therefore avoids fixed numerical cutoffs and instead requires explicit documentation of what evidence supports escalation and what remains unresolved.

Finally, plausibility must remain distinct from demonstrated transmission. Risk analysis of H5N1 and raw-milk exposure highlights the need to separate hazard detection, viable exposure, dose or route evidence, and direct evidence of infection or transmission [16]. Escalation may be justified before all uncertainties are resolved, but the evidential basis and residual uncertainty should remain visible at every decision point.

Veterinary-to-public-health information transfer

Translation fails when a veterinary alert is transmitted as a result without the evidence needed to interpret it. A cross-sector laboratory exercise involving foodborne pathogens separated detection, characterization, and notification as distinct surveillance functions and showed that weaknesses can arise at each step [17]. For animal-origin zoonotic signals, transfer should preserve specimen identity, host context, analytical confidence, characterization status, exposure relevance, uncertainty, and notification status. The proposed architecture treats these as an information package rather than a binary alert.

Information can also be lost through language. Cross-sector terminology work has shown that human-health, animal-health, and food-safety sectors may use non-equivalent terms, making shared definitions part of practical interoperability [18]. Organizational ambiguity compounds this problem. A Portuguese One Health simulation identified coordination gaps, unclear roles, and a need for shared reporting and common messages [19]. Thus, transfer quality depends on technical fidelity, semantic compatibility, and responsibility clarity. None alone guarantees action, but omission of any can distort the downstream risk state or delay reassessment.

Cross-sector communication

Cross-sector communication begins after information has been made interpretable, but it is not synonymous with information transfer. Semantic interoperability addresses whether sectors understand the same terms in compatible ways [18]; operational coordination addresses who receives information, who interprets it, who is authorized to act, and how disagreements are resolved. Keeping these functions separate matters because a technically accurate report may still fail if responsibility for interpretation is diffuse.

Simulation evidence supports explicit role assignment and shared situational outputs rather than parallel sector-specific narratives [19]. Laboratory exercises likewise show that technical detection and notification performance can fail at different points, so communication problems should not automatically be attributed to laboratory sensitivity or vice versa [17]. The proposed architecture separates signal transfer, interpretation, decision ownership, and coordinated outward messaging while preserving disagreement. Veterinary, environmental, occupational-health, and public-health teams may reasonably assign different confidence to the same evidence because their denominators, surveillance sensitivities, and action mandates differ. A defensible One Health process should expose those differences and their evidential basis rather than force premature consensus.

Public risk communication

Public communication is a decision intervention with its own uncertainty. In a Dutch population survey, zoonotic-risk attitudes varied across sociodemographic, communication, and health-related characteristics [20]. A single message can therefore misfit audiences differing in knowledge, exposure, vulnerability, or trust. Audience segmentation should not imply manipulative targeting; its purpose is to match information detail, protective guidance, and uncertainty statements to the people most affected.

Message construction also matters. A randomized Zika communication experiment found that metaphor could increase perceived susceptibility under some severity conditions rather than uniformly across conditions [21]. This supports calibration, not a preferred rhetorical device. More risk-amplifying language is not inherently more accurate or more useful.

Risk perception is also temporally unstable. Repeated surveys during avian and seasonal influenza periods showed that public perceptions changed over time and did not simply track objective epidemiological risk [22]. Communication should therefore be reassessed as evidence and audience interpretation change. The proposed architecture keeps public perception distinct from biological risk: misunderstanding can justify communication adjustment, but it should not itself upgrade or downgrade the underlying zoonotic hazard.

A proposed animal-to-human action architecture

The central contribution of this article is a proposed conditional architecture that converts veterinary detection into a revisable decision state without converting heterogeneous evidence into an unsupported score. Risk assessment methods are most defensible when they make data availability, analytical constraints, time pressure, and uncertainty explicit [15]. The architecture therefore places six evidence domains in parallel: veterinary detection quality and animal context; pathogen characteristics; human exposure pathway; exposure intensity and duration; human susceptibility; and environmental persistence. Cross-sector transfer then determines whether these domains reach the appropriate decision actors with sufficient context [17].

The architecture is deliberately noncompensatory. High pathogen consequence cannot by itself establish meaningful human exposure; plausible exposure cannot establish transmission; host vulnerability cannot compensate for an analytically uncertain animal signal. Conversely, confirmed human infection can justify reassessment even when earlier exposure confidence was low. Public communication remains an action domain whose calibration depends partly on audience heterogeneity [20], not a proxy for biological hazard.

Four proposed decision states organize action: observation, verification, exposure-focused escalation, and coordinated cross-sector action. Movement is conditional rather than linear, and every state can return to investigation when evidence is contradicted, becomes stale, or changes in scope.

Table 2 presents evidence requirements and permitted actions across four animal-to-human escalation states.

Table 2. Evidence requirements and permitted actions across four animal-to-human escalation states

Escalation question	Observation	Verification	Exposure-focused escalation	Coordinated cross-sector action
Meaning of the state	Animal signal present; human relevance unresolved	Signal requires stronger characterization	Credible human contact pathway is present	Multiple domains converge or human infection is detected
Evidence that defines it	Credible detection with limited interface evidence	Incomplete assay, host, specimen, or context information	Route-compatible contact, persistence, or susceptible host context	Compatible animal, exposure, human, or surveillance evidence
Cross-sector response permitted	Maintain surveillance and contextualize	Resolve uncertainty and map possible interfaces	Intensify exposure investigation and protective action	Coordinate public-health, veterinary, occupational, and communication functions
Inference not permitted	Detection is not exposure	Missing information cannot be scored as absence	Plausibility is not transmission	Action can precede complete certainty
Condition for leaving the state	Escalate if exposure or phenotype evidence changes	Return to observation or escalate after verification	Reassess with clinical or virological human evidence	Downgrade, maintain, or intensify as evidence changes

The architecture's conditional structure is compressed visually in **Figure 1** so that evidential boundaries and noncompensatory relationships remain explicit rather than disappearing inside a single risk label.

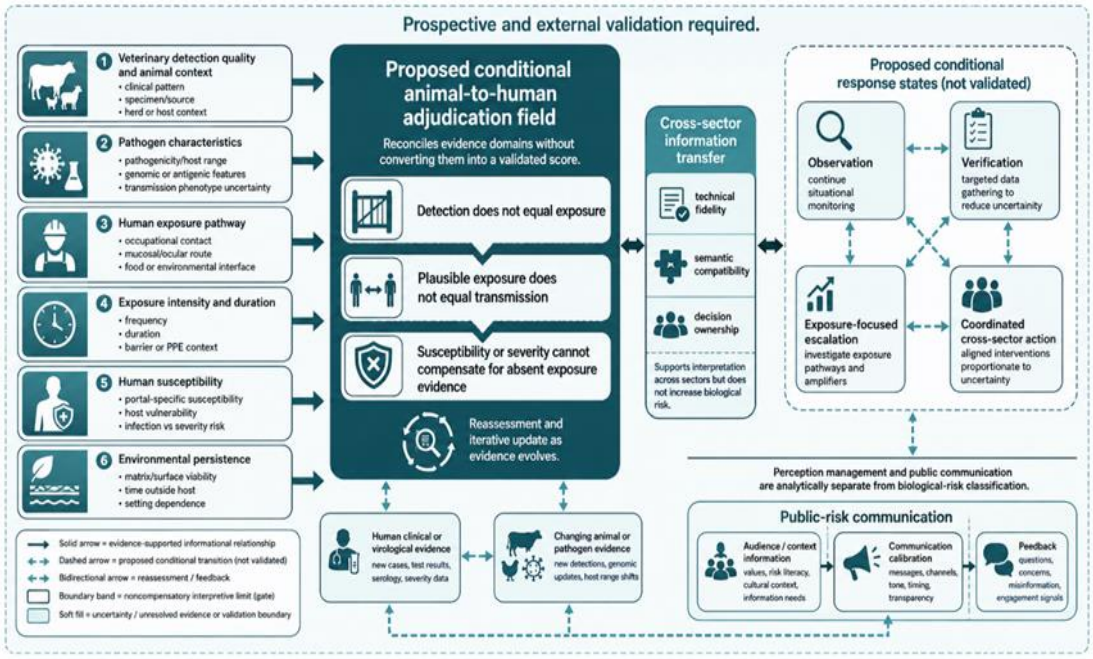

Figure 1. Risk escalation requires crossing distinct evidence boundaries rather than accumulating interchangeable signals

Response states from observation to escalation

Response should be proportional to the evidence state, not merely to pathogen notoriety. Ecological spillover scholarship shows that intervention opportunities exist before confirmed human transmission, including actions directed at reservoirs, interfaces, and exposure opportunities [23]. This supports an active observation state in which surveillance, characterization, and exposure mapping continue while human relevance remains uncertain.

Reassessment becomes more urgent when animal biology changes the exposure opportunity. Controlled H5N1 infection studies in cattle show that tissue and temporal dynamics matter when interpreting where infectious material may occur [24]. Field investigation of affected dairy farms likewise demonstrates that specimen type, clinical pattern, and production-network context can transform the meaning of a nominally similar detection [25]. Neither evidence source supplies a universal action threshold.

The proposed escalation states match actions to the barrier evidence can plausibly modify. Ecological intervention theory similarly distinguishes interventions acting on reservoir infection, pathogen release, environmental contact, and recipient exposure [26]. Escalation should thus change the scope and ownership of action while preserving the reason for the transition, the unresolved uncertainty, and a route back to lower-intensity response when evidence weakens.

Feedback from human surveillance

Human surveillance is not merely the endpoint of animal-origin risk assessment; it can revise the interpretation of the animal signal itself. A confirmed dairy-worker H5N1 infection supplied downstream evidence that was unavailable when cattle infection was first recognized [8]. Likewise, characterization of a human isolate can modify understanding of pathogen phenotype and justify renewed scrutiny of assumptions based on earlier animal isolates [7]. Feedback therefore operates in both evidential and operational directions.

Public perception can change over time independently of objective epidemiological risk [22]. Such divergence should trigger reassessment of communication, information needs, or audience segmentation without automatically altering the biological risk state. The proposed architecture consequently separates human clinical and virological surveillance from communication feedback while allowing both to modify subsequent decisions.

Figure 2 makes this distinction explicit by showing human surveillance as a source of evidence that can revise animal-origin adjudication, while public interpretation modifies communication strategy through a separate pathway.

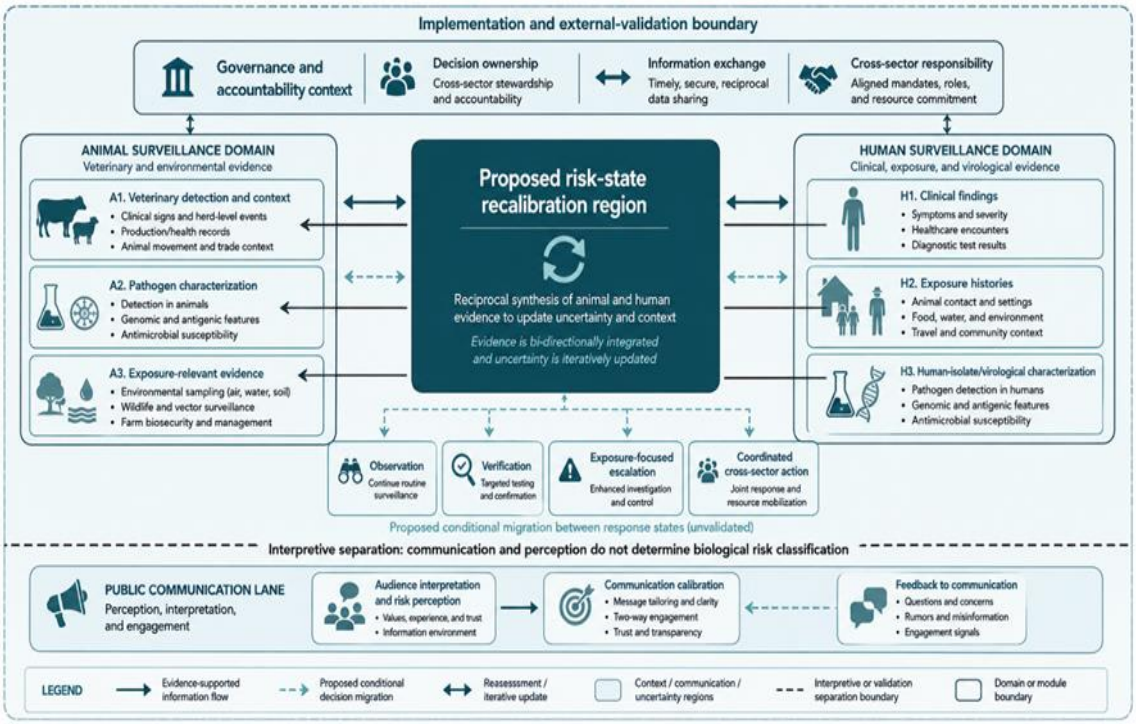

Figure 2. Human surveillance can revise animal-origin risk states without erasing source uncertainty

Governance and Accountability

Technical evidence cannot produce coordinated action if authority and accountability remain fragmented. Mixed-methods work in Mexico identified barriers including weak coordinating structures, legal fragmentation, limited information exchange, and resource constraints [27]. These findings support treating governance as a decision condition.

Governance also depends on capacities that are not reducible to formal authority. Systems leadership and health literacy have been proposed as interacting contributors to One Health implementation alongside governance [28]. That relationship remains conceptual rather than a demonstrated causal mechanism, but it highlights why assigning a lead organization may be insufficient when participating sectors cannot interpret or mobilize shared evidence.

Institutional arrangements also vary. Comparative analysis of Ghana and India showed that collaboration patterns and One Health policy positioning differed by national and hazard context [29]. A universal accountability template is therefore inappropriate. Consistent with this heterogeneity, application of OH-EpiCap across multiple European surveillance systems found uneven strengths and weaknesses across organization, operational activities, and impact-related dimensions [30]. The architecture consequently requires explicit ownership of interpretation, escalation, communication, and reassessment while leaving the institutional form jurisdiction-specific.

Implementation barriers

Implementation barriers arise at several separable levels. Recent wildlife-zoonosis literature indicates incomplete integration of environmental, social, and participatory dimensions, showing that nominally multisector research can remain structurally fragmented [3]. Semantic mismatch adds another barrier: sectors may exchange data while attaching different meanings to the terms used to describe them [18]. Neither problem is solved simply by creating an additional reporting channel.

Institutional barriers can then interrupt translation after evidence has been generated. Governance research documents constraints involving authority, information exchange, legal arrangements, workforce, and resources [27]. Surveillance-capacity assessments similarly show that systems can differ across organization, operational activity, and impact-related capabilities [30]. These barriers should not be collapsed into one “readiness” label.

The proposed architecture is modular: a system may detect a zoonotic signal yet remain weak in exposure investigation, semantic interoperability, decision ownership, or public communication. Implementation assessment should identify which function is limiting performance and whether that limitation changes the interpretation of the risk state, the feasibility of the response, or only the speed with which a justified response can be executed.

Validation priorities

The architecture requires validation as a decision system, not merely acceptance as a conceptual diagram. Guidance on developing One Health surveillance systems emphasizes shared objectives, coordination, data integration, and evaluation across traditionally siloed sectors [31]. Initial testing should therefore examine whether users can apply the proposed evidence domains consistently, distinguish uncertainty from absence, and document why a state transition occurred.

Structured evaluation tools demonstrate that organization, operational activities, and impact can be assessed as distinct surveillance dimensions [32]. For this architecture, reliability, interpretability, and calibration should be established before any numerical threshold or automated score is contemplated. Systems-oriented One Health evaluation further argues for examining organization, learning, collaboration, and outcomes rather than one endpoint [33].

Ultimately, feasibility is not effectiveness. Quantitative evaluation of cross-sector interventions requires explicit stakeholder objectives, linked compartments, and methods matched to the outcomes under study [34]. Appropriate future work therefore includes retrospective reconstruction of known events, interrater testing, prospective multicenter pilots, time-to-transfer analysis, external validation across pathogens and jurisdictions, and evaluation of whether changed decisions produce measurable benefits or unintended consequences. The architecture should be refined, challenged, or rejected if those tests do not support its assumptions.

Conclusion

Veterinary detection is best understood as the beginning of zoonotic risk interpretation rather than a direct proxy for human danger. The proposed architecture preserves distinctions among pathogen phenotype, animal context, exposure, susceptibility, persistence, evidential confidence, communication, governance, and feedback while supporting revisable response states. Its principal value is conceptual discipline: it makes visible which boundary has been crossed, which evidence remains missing, and why escalation or de-escalation is being considered. The architecture does not supply a universal risk score, validated threshold, or guaranteed pathway to effective action. Its utility will depend on whether diverse sectors can apply it consistently, whether it improves timely and interpretable information transfer, and whether prospective evaluation demonstrates better decisions without creating avoidable burden, inequity, or false confidence.

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