BEACON BIO · OPEN CONCEPT PAPER

Is biology the last unmeasured building system?

An open enquiry into Biological Infrastructure Intelligence

A Beacon Bio concept paper · Circulated for challenge, not agreement

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> About this paper
>
> This is a question-led concept paper, not a set of conclusions. Every section poses an open question, sets out how far the reasoning currently goes, and states plainly what remains unknown.
>
> It is circulated to people who know more than the author about parts of it — timber pest and structural biology, building services, facility management economics — in the hope of being argued with. Where a claim is speculative it is labelled speculative. Where a number is modelled rather than measured, it says so.
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> Nothing here is a validated method. That is the point of asking.
>
> Three propositions we are testing
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> 1. THE DATA MAY ALREADY EXIST Most environmental variables that drive biological risk appear to be collected already by building management systems — labelled with their mechanical purpose, and read by nobody asking a biological question.
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> 2. THE OPPORTUNITY MAY NOT BE CHEAPER SERVICE It may be replacing fixed-interval preventive maintenance with measured biological risk. The technician still attends — when the data says risk is rising.
>
> 3. THE BINDING CONSTRAINT MAY BE ORGANISATIONAL, NOT TECHNICAL Read-only integration of fifty points is straightforward. Getting three disciplines to share a location model and a record is the hard part.

In brief

— Buildings became continuously observable as *mechanical* systems over three decades. Their *biological* condition — moisture, microbial growth, timber decay, termite pressure, pest activity — remains fragmented across disciplines, contracts and formats that never meet. Is that fragmentation a real operational problem, or an academic observation?

— This paper explores Biological Infrastructure Intelligence (BII): a possible framework combining existing telemetry, targeted sensing, structured professional observation and building context. A companion idea, Biological Pressure, would express biological risk as interacting conditions over time rather than isolated incidents. Both are proposed concepts, unvalidated.

— On illustrative assumptions, risk-triggered servicing models a 31% and 42% reduction in total annualised cost across two cases. The load-bearing assumption is a halving of residual risk, and it is untested. Section 9 also asks the harder commercial question: who captures that value — the client, or the provider?

- Adjacent variables, notably indoor air quality, have already made this journey from invisible to operationally measured. Does that precedent transfer to biology, or is biology different in kind?
- Three moves are available now regardless: consolidate the biological record, standardise observation, adopt a shared location model. All three are procurement decisions, not technology projects.

01 HAVE BUILDINGS LEARNED TO DESCRIBE EVERYTHING EXCEPT THEIR BIOLOGY

Have buildings learned to describe everything except their biology?

Your building knows its own temperature to a tenth of a degree. It knows static pressure in the supply duct, runtime hours on chiller two, kilowatt-hours burned last Tuesday between 14:00 and 15:00, and the moment a damper actuator started drawing more current than it should.

It has no idea there is a rat in the ceiling.

Every operational domain in the built environment follows the same maturity path: response, inspection, measurement, interpretation. Mechanical services have reached stage four. Fault detection and diagnostics, standardised sequences of operation such as ASHRAE Guideline 36, and outcome-based facility management have seen to that.

Biological condition sits at stages one and two.

EXHIBIT 1 · MECHANICAL SERVICES REACHED INTERPRETATION; BIOLOGY NEVER LEFT INSPECTION

STAGE	OPERATING QUESTION	TRIGGER	ARTEFACT	MECHANICAL	BIOLOGICAL
1. RESPONSE	What broke?	Failure, complaint	Work order	Historic	Common
2. INSPECTION	Is anything wrong?	Calendar	Inspection report	Historic	Dominant
3. MEASUREMENT	What is the state now?	Continuous sensing	Trend log	Standard	Rare
4. INTERPRETATION	What does it mean next?	Analytics, models	Prioritised investigation	Emerging	Absent

This is not a criticism of anyone's competence. It is an observation about architecture. Pest management is procured as a periodic service with an escalation path. Moisture investigation is triggered by visible damage. Indoor air quality assessment is episodic. Each produces information. Almost none of it lands in the same place, format or timeline as the telemetry the building generates every fifteen minutes.

The asymmetry is stark. A facility manager retrieves two years of return air temperature in under a minute — and cannot retrieve two years of moisture, pest and remediation history from a single system at all, because it lives in a provider's portal, a PDF, a maintenance log, a photograph on somebody's phone, and an email thread beginning "RE: RE: FW:".

> The question nobody can answer

> Had a building recorded biological observations with the discipline it applies to chilled water supply temperature, how many of last year's biological problems would have been visible before they became problems?
>
> Nobody knows. That is the point.

> OPEN QUESTION *Is the asymmetry in Exhibit 1 a genuine operational deficiency, or simply the correct allocation of attention to systems that fail expensively and predictably?*

02 WHAT IS THE BMS ALREADY TELLING US — AND WHAT IS IT NOT

What is the BMS already telling us — and what is it not?

Before proposing new sensing, be honest about what existing telemetry can support.

Building management systems are engineered to control mechanical services. Their architecture — field controllers, supervisory controllers, front-end supervision, integration via BACnet, Modbus or KNX — is built around points, objects, setpoints, alarms and trends (Kawa, Borkowski and Rodak, 2021).

AVAILABLE AND RELIABLE Space and duct temperature, relative humidity, differential pressure, CO_2 in some spaces, airflow, valve and damper position, run status, alarms, energy and water metering, and increasingly occupancy.

AVAILABLE BUT UNEVEN RH sensors drift. Point naming is inconsistent. Trend retention varies from weeks to years. Legacy plant is integrated through gateways that flatten useful detail. Metadata — what a point actually represents — is usually the weakest link in the chain.

NOT AVAILABLE Surface moisture in wall cavities. Water activity in building fabric. Microbial presence. Pest activity. Envelope condition. Waste practice. Surrounding ecology.

There is also a human constraint no architecture diagram shows. In most buildings the person who truly understands the point list is one contractor's engineer who set it up years ago, named half the points after drawing sheets and the other half after his own logic, and has since moved firms. Every estate has this person. Few have his notes.

TWO CONSTRAINTS BOUND THE ARGUMENT First, existing telemetry describes the *conditions* in which biology occurs — not the biology. Temperature and humidity are enabling factors, not organisms; a framework that forgets this produces confident nonsense at scale. Second, much of the built stock — small commercial, older industrial, and much of the hospitality and food sector that pest management serves most intensively — has minimal telemetry or none.

> OPEN QUESTION *How much of the built stock has enough telemetry and enough retention for any of this to apply — 5% of buildings, or 40%?*

03 IS HVAC DATA AN ACCIDENTAL BIOLOGICAL SENSOR NETWORK

Is HVAC data an accidental biological sensor network?

This is the part of the argument that costs almost nothing, and is therefore the most interesting.

Nobody installed a return-air humidity sensor to think about mould; it was installed to control a coil. Nobody meters a cool-room compressor to think about cockroaches. Yet each of those points describes, continuously and for free, a condition that biology cares about a great deal.

A large share of the variables driving Biological Pressure are already sensed in commercial buildings — labelled with their mechanical purpose. The data is not missing. The interpretation is.

Can the same point be read twice?

EXHIBIT 2 · ELEVEN ORDINARY POINTS, EACH WITH A BIOLOGICAL SECOND MEANING

BMS POINT	WHY IT EXISTS	WHAT IT MAY ALSO DESCRIBE
RETURN AIR RH	Coil and dehumidification control	Sustained moisture availability in the zone
SPACE TEMP VS SETPOINT DEVIATION	Comfort performance	A zone warm or cold enough to change biological rates
CHILLED WATER VALVE POSITION AT LOW LOAD	Control stability, energy	Valve leaking by → overcooled surfaces → condensation
AHU OFF-HOURS RUN STATUS	Energy management	Long unventilated periods with heat and moisture retained
ZONE DIFFERENTIAL PRESSURE	Contamination control	Lost pressure regime → ingress path for air, odour, insects
CONDENSATE PUMP CYCLES / ALARM	Plant protection	Standing water and a persistent wet reservoir
COOL-ROOM DOOR AND DEFROST CYCLING	Product protection	Warm humid air meeting cold surfaces at a known interval
FAN SPEED, FILTER DIFFERENTIAL PRESSURE	Maintenance scheduling	Loading rate — dust, organic matter, biological load
WATER METERING, NON-ZERO OVERNIGHT BASELINE	Leak detection, cost	A continuous hidden water source in the fabric
DOOR COUNTS, OCCUPANCY	Space utilisation	Food traffic, waste generation, door-open time
OUTSIDE AIR DAMPER VS EXTERNAL CONDITIONS	Economiser control	How much external environment is invited in, and when

No reading here proves anything biological. A leaking valve is not mould. An overnight water baseline is not a rat. What each provides is a condition with a duration — and duration is what distinguishes a nuisance from a habitat.

That is the single most useful idea in this paper for anyone operating a BMS. *The biological question is rarely "what is the value?" It is "how long has it been that way?"* A humidity reading of 78% means little. A reading of 78% sustained across nine of the last eleven days, in a zone whose AHU has been off outside business hours, means a great deal.

What would integration actually require?

Facility managers are reasonably tired of being told to integrate things. So be specific.

READ-ONLY, ALWAYS The biological layer subscribes. It does not write points, adjust setpoints or touch schedules. In practice: a BACnet client with read privileges, a Niagara station exposing a filtered subset, a historian export, or an API from an existing analytics platform. Whatever the controls contractor is least nervous about is usually the right answer.

FIFTY POINTS, NOT FIVE THOUSAND A building has thousands of points; a biological overlay needs thirty to eighty, chosen against specific questions. Requesting a full point export is how these projects die in the security review.

LOCATION IS THE JOIN KEY Telemetry knows AHU-03 and VAV-2-14. The technician knows "the loading dock" and "the store room behind the kitchen." Reconcile them to a shared spatial model or nothing combines. This exercise is dull, manual, and the highest-value hour on the project.

RETENTION BEATS RESOLUTION Fifteen-minute trends are ample; nobody needs one-second data to understand moisture persistence. Retention binds — biology moves in seasons, and ninety days of history cannot see a pattern that repeats each autumn.

EXHIBIT 3 · SEQUENCE INTEGRATION BY VALUE PER DOLLAR, NOT BY DEMO QUALITY

MOVE	COST	VALUE	VERDICT
MAP EXISTING POINTS TO A SHARED LOCATION MODEL	Low, mostly labour	High — unlocks everything else	Do first
READ-ONLY FEED OF ~50 POINTS	Low–moderate	High	Do second
STRUCTURE TECHNICIAN OBSERVATION TO THE SAME MODEL	Low	High	Do in parallel
TARGETED SENSING IN UNMONITORED RISK ZONES	Moderate	Question-dependent	Do third, sparingly
CONNECTED PEST MONITORING DEVICES	Moderate	Moderate alone, higher in context	Only after Layer 1
FULL DIGITAL TWIN WITH 3D VISUALISATION	High	Low near-term	Do last, or never
ANY WRITE ACCESS TO BUILDING CONTROL	—	—	Do not

Most failed integrations invert this ordering. They start with the visualisation because it demonstrates well in a boardroom, and discover eighteen months later that no point was ever mapped to a place a human could stand.

What might this look like in a building?

> **READ THESE AS CONSTRUCTED ILLUSTRATIONS, NOT CASE STUDIES** Both are built from individually well-established mechanisms — condensation on cold surfaces, moisture-driven microbial growth, resource-driven pest activity — assembled to show how the reasoning works. Neither sequence has been measured and validated. They are exactly what the research agenda in Section 11 exists to test.

ILLUSTRATION A — THE SUPERMARKET BACK-OF-HOUSE A metropolitan supermarket has recurring cockroach activity in the rear preparation area. It is treated quarterly and returns quarterly. Each report reads, in effect, "activity observed, treatment applied, monitor." Everyone is doing their job.

Read biologically, the refrigeration and HVAC telemetry tells a longer story. The cool-room defrost cycle was extended eight months earlier following a compressor fault — a sensible mechanical decision. Each extended cycle produces a longer period of warm humid air meeting cold surfaces. The condensate pump on that plant runs more often than its neighbours. Back-of-

house exhaust has run at reduced speed since a belt replacement, leaving the space marginally positive to the loading dock rather than negative. Dock door-open time is up seasonally.

No single item is an alarm. None would raise a work order. Together they describe a space that has quietly become warmer, wetter, better connected to the outside and more welcoming than a year ago. The reading is not "there are cockroaches." It is: *the conditions that make this a good place to be a cockroach have measurably improved, and treatment is being applied to a habitat getting better at regenerating.* The intervention that changes the outcome is a fan belt, a condensate line and a door regime — not a fourth treatment.

ILLUSTRATION B — THE OVER-SERVED OFFICE FLOOR A tower has an intermittent musty odour on level nine, present some weeks and not others. Two IAQ assessments found nothing conclusive, both having been carried out on days the odour was absent — a coincidence familiar to anyone who has tried to reproduce an intermittent fault for a consultant.

Telemetry shows a chilled water valve on the level-nine AHU that never fully closes. On mild days at low load the coil continues to be served, supply air runs colder than required, and downstream surfaces sit below dew point for extended periods. Complaint weeks track *mild and humid* weather, not hot weather — which is why nobody looked there.

The value is not detecting mould; nobody has established mould is present, and the framework must not pretend otherwise. The value is directing the investigation to the right place at the right time: sending the hygienist on a mild humid day rather than whenever the diary allowed.

Both illustrations share a structure. A competent mechanical decision produced a biological consequence nobody was watching for, and the discipline responding to it had no visibility of the cause.

What would it mean for system integration?

THE BMS BECOMES A CONTEXT SERVICE, NOT A CLOSED CONTROL SYSTEM Its data already serves energy, maintenance, ESG reporting and occupant experience. A biological consumer is another read-only subscriber to the same environmental history — architecturally unremarkable, which is precisely why it is feasible.

PEST AND REMEDIATION PROVIDERS BECOME DATA PRODUCERS This is the harder half: structured capture at the point of observation, requiring workflow change, training and standards. Sensors are the easy part; the people are the project.

The biological record becomes an asset of the building, not the contractor. Today that history belongs to whoever holds the contract and leaves with them. Moving it to the asset owner is a procurement decision available now, requiring no technology at all.

Most of what this section proposes is not a technical problem. It is a paperwork problem wearing a technical costume.

> OPEN QUESTION *Would a controls contractor, an FM and a pest provider actually agree a shared location model — and if not, does the whole idea stop at that sentence?*

04 IS THE SCIENCE SETTLED, AND ONLY THE OPERATIONS MISSING

Is the science settled, and only the operations missing?

That buildings host biology is not a new discovery, and this paper claims no originality on the point. Martin and colleagues (2015) described the "indoor biome" as a distinct, rapidly expanding ecological environment with its own selective pressures and inhabitants — microbial, arthropod and vertebrate. The National Academies' 2017 research agenda, *Microbiomes of the Built Environment*, set out how building attributes shape indoor microbial communities and named sensing, monitoring and modelling as priority directions.

Humans spend most of their lives inside structures that are, biologically, novel habitats with reliable climate control, abundant organic matter and few predators. It would be surprising if nothing moved in.

What is underdeveloped is not the science but its operational integration. The knowledge exists — in indoor microbiology, building science, public health, hygrothermal engineering, entomology and IAQ research. It does not exist in a form a duty facility manager can act on at 08:30 on a Monday.

Every building professional already knows this in their body, if not in their data. Ask a facility manager with a few years on site and they will tell you which corner of which level smells different in February, which riser is "always damp," and which loading dock has never been sealed properly despite three scopes of works. That knowledge is real, accurate, and stored entirely in one person who will eventually retire.

EXHIBIT 4 · BIOLOGICAL SIGNALS SHARE NO DATA MODEL; MECHANICAL SIGNALS DO

SIGNAL	OWNER	CADENCE	FORMAT	IN THE BMS?
PEST ACTIVITY	Pest contractor	Monthly / quarterly	Portal, PDF	No
MOISTURE / LEAKS	Maintenance, remediation	Reactive	Work order	Partially
MOULD / MICROBIAL	Hygienist	Incident-driven	Lab report	No
INDOOR AIR QUALITY	Consultant	Episodic	Report or trend	Sometimes
BUILDING FABRIC	Surveyor	Annual or longer	Condition report	No
CLEANING AND WASTE	Soft services	Daily	Checklist	Rarely
OCCUPANCY	BMS, security	Continuous	Trend	Often
EXTERNAL ENVIRONMENT	Public weather data	Continuous	Feed	Rarely

The pattern is visible on one reading. Signals that share a data model are already inside the BMS. Everything else is an island with its own boat.

> OPEN QUESTION *Is the operational gap real, or does it only look like a gap to someone who has not sat in a well-run FM team?*

05 IS FRAGMENTATION THE REAL PROBLEM, RATHER THAN IGNORANCE

Is fragmentation the real problem, rather than ignorance?

This paper treats fragmentation as a hypothesis to be tested, and invites readers to falsify it in their own estates.

> Biological information about a building is generated in sufficient volume to be operationally useful, but is distributed across disciplines, contracts, vendors, formats and timescales in a way that prevents it from being interpreted as a single changing condition.

Three consequences follow if it holds.

ONE ROOT CONDITION BECOMES MANY UNRELATED INCIDENTS A persistent minor plant-room leak may generate, over eighteen months: a maintenance call-out, a mould remediation, a pest treatment, an odour complaint and a flooring repair. Five jobs, five invoices, five records, one cause.

PREVENTION IS STRUCTURALLY DISADVANTAGED Incident-based models are paid for incidents. Nobody is positioned to be paid for the incident that did not happen — which is why "preventive" has historically meant more frequent inspections rather than understanding of causes.

LONGITUDINAL LEARNING DOES NOT ACCUMULATE When a contract changes hands, operational memory leaves with it. Twelve years of thermal history stays. Twelve years of pest and moisture history goes into a box, or a portal that is switched off.

Three fair challenges deserve straight answers. *Is this already covered by IAQ and building science practice?* Partially — in the minority of buildings where such practice is well funded and continuous, and even there it is air-focused rather than covering pests, fabric and moisture as one picture. *Are the variables too heterogeneous to unify?* This is the strongest objection in the paper. A cockroach, a fungal spore and a saturated plasterboard sheet share no units; what they may share is a set of *enabling conditions*, and that is what the framework models. *Does this beat a competent inspector who knows the building?* Frequently, no. The proposal is not to replace that judgement but to give it memory, context and a longer time horizon.

> **OPEN QUESTION** *Can any reader falsify the fragmentation hypothesis in their own estate in one afternoon? If so, this paper needs rewriting — which would be a useful outcome.*

06 CAN BIOLOGICAL RISK BE EXPRESSED AS A CONDITION RATHER THAN AN EVENT

Can biological risk be expressed as a condition rather than an event?

Biological Pressure is proposed as a way of expressing biological risk as an interacting, time-varying condition rather than a discrete finding.

The intuition is familiar to anyone who has run a pest operation. A single cockroach in clean, dry, well-sealed food premises means something entirely different from a single cockroach in a warm, humid building with a damp sub-floor, an unmanaged waste enclosure, a defective door seal and a mild wet winter. Same observation. Different condition.

Watch a good technician enter a site: they look at the door sweeps before they look for the pest, notice the smell of the drain, and glance at where the bins sit relative to the back door. They are already running the model. What they lack is a way to write it down, track it, and hand it to a client as evidence — which is why so much of that judgement ends up as one line reading "treatment applied."

Candidate inputs include moisture availability and its persistence; temperature and RH in operating ranges rather than averages; food and resource availability including waste handling; ingress pathways and envelope condition; occupancy and behaviour; airflow and pressure relationships; surrounding ecology and adjacent works; sanitation and drainage; pest observations including smart monitors; microbial or IAQ indicators; and seasonality and antecedent weather.

EXHIBIT 5 · PRESSURE LOGIC CHANGES THE UNIT OF WORK, NOT JUST THE REPORTING

	INCIDENT LOGIC	PRESSURE LOGIC
UNIT OF ATTENTION	The finding	The condition
TIME HORIZON	Point in time	Trajectory
QUESTION ASKED	What did we find?	What is becoming more likely,

	INCIDENT LOGIC	PRESSURE LOGIC
		and why?
TYPICAL RESPONSE	Treat	Investigate, then decide
SUCCESS MEASURE	Issue closed	Condition changed
WHAT THE CLIENT BUYS	Attendance	Reduced likelihood

Three constraints attach, and they are not decorative. It is not a score until validated as one — the temptation to produce a single number between 0 and 100 is immense because single numbers sell, and a number not validated against outcomes is a marketing device wearing a lab coat. It must not imply diagnosis — conditions indicate that a situation is *conducive*; they cannot establish microbial growth, identify a species or characterise health risk. It must survive a literature collision check before publication.

> OPEN QUESTION *Are enabling conditions genuinely shared across termites, decay fungi, cockroaches and rodents — or does each need its own model, making "Biological Pressure" a label rather than a mechanism?*

07 WHAT WOULD A FRAMEWORK LOOK LIKE — AND WHERE MUST IT STOP

What would a framework look like — and where must it stop?

Biological Infrastructure Intelligence integrates environmental telemetry, biological observation, building condition data and operational context to interpret biological conditions in the built environment.

EXHIBIT 6 · THE FRAMEWORK: FOUR LAYERS OF INPUT, ONE LAYER OF HUMAN DECISION

LAYER 1 — EXISTING TELEMETRY BMS and BAS points, HVAC operation, alarms, metering, occupancy. Read-only. Free — the building already produces it.

LAYER 2 — TARGETED SENSING Only where a specific question justifies it: moisture and leak detection, in-fabric moisture, particulates, CO_2, temperature and RH in unmonitored voids, connected pest monitors. Add sensors to answer questions, not to look for them.

LAYER 3 — PROFESSIONAL OBSERVATION Technician, hygienist, surveyor, thermographer — structured so observation becomes data: consistent fields, locations, severity language, photographs tagged to assets. Where most operations can improve immediately, at almost no capital cost.

LAYER 4 — INTERPRETATION Correlate across time and space, detect anomaly and drift, express uncertainty honestly, produce investigation priorities rather than conclusions.

LAYER 5 — HUMAN RESPONSE A competent person — facility manager, engineer, hygienist, licensed pest professional, building scientist — decides what to do.

> Governance rule
>
> The biological layer observes, interprets and recommends. It does not autonomously alter critical building control.
>
> This is not timidity. Control authority is a safety and liability matter, and an inference layer built on proxy measurement has no business adjusting a ventilation strategy on its own recognisance.

Three questions must stay separate: telemetry asks what is happening, and is answered by sensors; interpretation asks what it might mean biologically given context and uncertainty, and is answered by models plus expertise; recommendation asks what a qualified human should investigate next, and is advisory only. Collapse them and you have an expert system confidently diagnosing mould from a humidity sensor — a product recall waiting to happen.

> OPEN QUESTION *Where exactly should the line sit between advisory interpretation and regulated professional judgement, and who has standing to draw it?*

08 HAS ANY ADJACENT VARIABLE ALREADY MADE THIS JOURNEY

Has any adjacent variable already made this journey?

The strongest evidence that this transition is feasible is not theoretical.

Indoor air quality was, within recent memory, largely invisible to routine building operations — assessed episodically, after complaints. It is now the subject of sustained argument for explicit, measurable performance requirements in public buildings (Morawska et al., 2024), with the pandemic accelerating attention to ventilation as an operational rather than design-time concern. ASHRAE's proposed Standard 235P indicates movement toward a broader indoor environmental quality framing — accurately described as work in progress.

The interpretation and control layers are equally demonstrated. Work optimising IAQ inside HVAC systems using deep reinforcement learning (Zhao et al., 2026) shows the full chain: a health-related variable becoming a sensed input, then an interpreted state, then an objective inside building control. Low-cost particulate sensing for compliance monitoring shows expensive-to-observe variables moving toward distributed sensing — *provided* data quality and governance are adequate, a proviso doing most of the work in that sentence. Digital twin work for the built environment (IET/Atkins) describes progressive maturity in information integration, and industry analysis of outcome-based FM (Cushman & Wakefield) indicates client-side appetite for condition-based rather than attendance-based service.

Note what is and is not claimed. Nobody has demonstrated Biological Infrastructure Intelligence. Each component capability has been demonstrated somewhere, for some variable. Whether they combine usefully for biological condition is open — that is the research agenda, not the finding.

> OPEN QUESTION *Indoor air quality had a pandemic to accelerate it. What would be the equivalent forcing event for biological condition, and does anything happen without one?*

09 COULD RISK-TRIGGERED SERVICING BEAT FIXED INTERVALS — AND WHO CAPTURES THE VALUE

Could risk-triggered servicing beat fixed intervals — and who captures the value?

The commercial argument is frequently misheard, so state it in one sentence.

> The proposition is not "replace pest control with technology." It is "replace fixed-interval preventive maintenance with measured biological risk."
>
> The technician still exists. The technician attends when the building data says risk is rising.

If it works, it changes the transaction for every party. The client stops buying attendance and starts buying reduced expected loss. The provider stops selling a calendar and starts selling knowledge of a building. And the technician — the part usually omitted — stops making eleven uneventful visits a year and starts attending when there is something worth attending to, which is a considerably better job.

Whether it *does* work is unresolved. The illustrations below set out the arithmetic and then ask the question that actually determines whether anyone should pursue this: who captures the value it creates?

What would the model be?

Biological Risk = probability of biological failure × consequence

Probability is driven by conducive conditions, exposure, asset vulnerability, biological evidence, and duration or trend. Consequence is a business number the client already knows or can estimate: remediation, disruption, product loss, regulatory and reputational exposure.

Operationally, a system might report *Timber Zone A — Risk 24/100 → continue monitoring*, and three months later *Timber Zone A — Risk 71/100 → targeted timber inspection required*.

The caution from Section 6 applies at full force: a number of this kind is a communication device pending validation, not a diagnostic instrument.

Illustration 1 — Timber risk, where the argument is strongest

Timber is where this argument is strongest, for a reason worth stating plainly: timber pest practice already thinks in conducive conditions. Australian inspection practice is built around moisture, ventilation, drainage, ground clearance, bridging and concealment — the assessment is already a conditions assessment, recorded qualitatively, once a year, by a person with a torch and a moisture meter.

The question this paper asks is narrow: could some of those conditions be observed continuously instead of annually?

EXHIBIT 7 · SOME CONDUCIVE CONDITIONS ARE ALREADY SENSED; MOST ARE NOT

CONDUCIVE CONDITION	CURRENTLY ASSESSED	CONTINUOUSLY OBSERVABLE TODAY?
ELEVATED MOISTURE NEAR STRUCTURAL TIMBER	Annual inspection, spot readings	Partly — via zone RH, condensate alarms, leak detection
PERSISTENT PLUMBING OR CONDENSATE LEAKAGE	On discovery	Yes — non-zero overnight water baseline, pump cycling
POOR SUB-FLOOR VENTILATION	Visual, annual	Sometimes — where sub-floor fans are on the BMS
WET AREAS AND SHOWER RECESSES	Visual, annual	Rarely — needs targeted sensing
DRAINAGE FAILURE AND POOLING NEAR FOOTINGS	Visual, seasonal	Partly — external rainfall data plus targeted moisture
GROUND CLEARANCE AND BRIDGING	Visual only	No — requires physical observation
CONCEALMENT AND INACCESSIBLE AREAS	Visual, noted as limitation	No — a permanent limit on any remote approach

Two conclusions fall out of that table, and they point in opposite directions. Several of the highest-value conducive conditions are already visible in building data. Several of the most important ones — bridging, concealment, ground clearance — never will be, which is a hard ceiling on how far any of this can go without a technician on site.

A commercial building already monitors condensate drains, humidity and moisture around HVAC equipment. The same telemetry could identify persistent conducive conditions near timber.

Assume a significant termite or decay event costs $120,000 in investigation, remediation, disruption and repair.

EXHIBIT 8 · RISK-TRIGGERED TIMBER INSPECTION MODELS A 31% LOWER ANNUALISED COST

MODEL	ANNUAL MAINTENANCE	RESIDUAL RISK	EXPECTED RISK COST	TOTAL ANNUALISED
TRADITIONAL TIMBER SERVICE CONTRACT	$8,000	4%	$4,800	$12,800
BMS RISK MONITORING + TRIGGERED INSPECTION	$6,400	2%	$2,400	$8,800

Expected risk cost = probability × consequence. The monitoring model comprises roughly $2,000 monitoring, $2,400 targeted inspection, and $2,000 amortised integration and setup. Illustrative saving: ~$4,000 per year, or 31%.

The saving is not the important part. The trigger for inspection changes from "*It has been 12 months; inspect the timber*" to "*This timber zone experienced abnormal moisture for 47 days; inspect it now.*"

Illustration 2 — Warehouse rodent risk

A food warehouse pays $12,000 annually for routine pest servicing. Under the alternative, risk is calculated from loading-door duration, waste activity, temperature, external pressure, rodent-monitor activity and proofing defects. Assume a significant contamination event carries an average business consequence of $60,000.

EXHIBIT 9 · INTEGRATED RISK MONITORING MODELS A 42% LOWER ANNUALISED COST

MODEL	ANNUAL MAINTENANCE	RESIDUAL RISK	EXPECTED RISK COST	TOTAL ANNUALISED
FIXED PEST CONTRACT	$12,000	10%	$6,000	$18,000
INTEGRATED RISK MONITORING	$7,500	5%	$3,000	$10,500

Illustrative saving: ~$7,500 per year, or 42%. Instead of twelve identical monthly visits, the building might receive two verification inspections in stable periods and several targeted interventions when risk rises.

> Read these numbers correctly
>
> Both exhibits are illustrative models built on stated assumptions, not measured results. Consequence figures are plausible order-of-magnitude estimates; residual-risk percentages are assumptions, not findings. The halving of residual risk in each case is the load-bearing assumption in the entire argument, and precisely the thing not yet demonstrated.
>
> Their purpose is to show the *shape* of the economics and make the assumptions explicit enough to argue with. Anyone presenting these as evidence of savings has misunderstood the paper — though they will not be the first to put an unvalidated percentage on a slide.

Who captures the value?

The tables above show the saving accruing entirely to the client. That is one possible outcome, and probably the least interesting one.

EXHIBIT 10 · THE SAME COST REDUCTION CAN BE DISTRIBUTED THREE WAYS

WHO CAPTURES IT	WHAT IT LOOKS LIKE	CONSEQUENCE FOR THE PROVIDER
CLIENT	Lower contract value, same scope	Revenue falls. Commoditisation risk.
PROVIDER	Same contract value, lower delivery cost	Margin rises. Fewer low-yield visits per technician per site.
SHARED	Modest price reduction, retained margin, longer term	Stickier account, higher switching cost, defensible position

The third column is the one worth arguing about. Under fixed-interval servicing, a provider's cost base is largely windscreen time and attendance. Risk-triggered servicing removes low-yield visits — which is a delivered-cost reduction the provider can capture rather than surrender, provided the offer is framed as a superior service rather than a discount.

There is also a defensive case. "We attended because it was March" is a weak position in a dispute. "We attended because this zone recorded 47 days of abnormal moisture and the risk score moved from 24 to 71" is a defensible one — and a documented reason for each intervention may prove more valuable than any saving, in a claim, an audit or a contested inspection.

> OPEN QUESTION *Open question: in a market where clients compare service contracts largely on price and frequency, can a provider realistically sell fewer visits at a sustained price — or does the first competitor to try it simply hand a discount to the market?*

ONE CAVEAT, STATED PLAINLY In food, healthcare and other regulated environments, compliance may still require scheduled inspection regardless of measured risk. There the model does not eliminate the service contract; it reduces unnecessary intervention within it and adds risk-based servicing on top — a smaller claim, and a more honest one.

> OPEN QUESTION *Would a large service organisation ever voluntarily reduce its own visit frequency, or does this only get built by someone with no existing revenue to protect?*

10 HOW WOULD THIS FAIL

How would this fail?

A framework that cannot describe its own failure is a brochure.

FALSE CONFIDENCE FROM PROXY MEASUREMENT The most serious risk. Conditions are enabling factors, not evidence of biological presence. A system reporting "elevated microbial risk" from a humidity trend has invented information. Language discipline is a safety control, not a style preference.

ANOTHER DASHBOARD If the output is one more screen of amber indicators, the framework has failed on its own terms. Most facility managers already have a monitor displaying a system nobody has looked at since commissioning — quietly amber, load-bearing for nothing. The test is whether a competent person acts differently, not whether it displays.

INFERENCE ON UNVALIDATED DATA Sensor drift, inconsistent naming, gaps and legacy limits are the normal condition of building data. Inference built on unverified points inherits every defect and adds confidence to it.

SCOPE CREEP INTO REGULATED JUDGEMENT Microbiological identification, health risk assessment and structural determination are credentialed domains. The framework must stop cleanly at investigation prioritisation. Governance keeps a useful tool from becoming an unlicensed diagnosis.

Alongside these: cost may exceed benefit in a single well-run building; occupancy and camera data touch people and require a privacy position established before deployment; and any connection to building systems must be read-only, segmented and governed.

THE HONEST FAILURE CONDITION if the framework produces correlations that are interesting but never actionable, or actions a competent professional would have taken anyway, it has failed and should be abandoned rather than rebranded.

> OPEN QUESTION *Which of these failure modes is most likely to occur first, and would anyone notice it happening?*

11 WHAT COULD BE TESTED NOW

What could be tested now?

Four moves available now, none requiring technology

CONSOLIDATE THE BIOLOGICAL RECORD Can you retrieve 24 months of pest, moisture, mould and remediation history for one building, from one place, in one afternoon? If not, that is the first fix — administrative, not technological.

STANDARDISE OBSERVATION Require structured fields, consistent locations and consistent severity language from every provider generating biological observations. A procurement decision, not an IT project.

ADOPT A LOCATION MODEL Telemetry and observation combine only if they agree on where they are. The unglamorous precondition for everything else.

ASK FOR CAUSES Change the standing question in service reviews from "what did you find and treat?" to "what conditions in this building make this recur?" The answer will be imperfect. Asking repeatedly changes what gets recorded.

And one free experiment: next time a recurring biological issue is raised, pull the BMS trends for that zone for the preceding three months and put them on the table beside the service report. It costs an hour. At worst they show nothing and the hypothesis weakens, which is also useful. At best somebody says "hang on, that's when we changed the schedule" — the entire thesis of this paper, delivered free by a person who was in the building all along.

Is the strategic point sharper for pest management than for FM?

Pest management sits on the highest-quality biological observation network in the built environment — trained people, in buildings, on a recurring schedule, looking for biological evidence. That network currently produces service records.

The opportunity is to treat observation as an information asset rather than a compliance by-product: structured capture, environmental context, longitudinal continuity across contract renewals, and reporting that describes conditions rather than counts.

The commercial consequence is the shift in Section 9 — from selling attendance to selling reduced expected loss. Stickier, higher-margin and more defensible than a monthly visit. Also harder to deliver, requiring technician standards, data discipline and route economics that do not

exist in most operations today. It requires, in particular, the confidence to tell a client they need fewer visits this quarter.

This is an operating capability to be built, not a feature to be purchased.

What would have to be researched?

1. **GROUND TRUTH AVAILABILITY** Does sufficient longitudinal biological observation data exist, anywhere, to validate environmental inference? Without it, everything downstream is speculation.
2. **PREDICTIVE LEAD TIME** Do combinations of conditions precede incidents by an operationally useful margin — weeks, not hours?
3. **RESIDUAL RISK REDUCTION** Does risk-triggered attendance actually lower incident probability relative to fixed intervals? This is the assumption the Section 9 economics rest on, and the one most worth attacking.
4. **DECISION IMPACT** Does interpreted information change professional decisions relative to raw observation? Critical, and measurable.
5. **HETEROGENEITY AND TRANSFERABILITY** Can pests, microbial growth and material deterioration be modelled through shared enabling conditions — and does anything learned in one building transfer to another?
6. **GOVERNANCE DESIGN** What is safe to automate, what must remain advisory, and what must never leave qualified human judgement?

EXHIBIT 11 · TEST THE PROPOSITION IN FIVE PHASES WITHOUT BETTING THE BUSINESS

PHASE	DURATION	OBJECTIVE	WHAT GOOD LOOKS LIKE
0. GROUND TRUTH	1–2 months	Assemble 24 months of biological and remediation records for 3–5 buildings	You discover how bad the records are. A finding, not a failure.
1. STRUCTURE OBSERVATION	3 months	Standardise fields, locations, severity language	Two technicians describe one condition the same way
2. CONNECT TELEMETRY	3 months	Read-only access to ~50 mapped points	Environmental history retrievable per zone
3. RETROSPECTIVE TEST	2 months	Test whether conditions preceded known incidents	A pre-registered hypothesis is supported, or it is not
4. PROSPECTIVE TRIAL	6–12 months	Advisory flags issued; measure decision change and residual risk	The Section 9 risk assumption is validated, or falsified

Phase 0 is the phase everyone wants to skip and nobody should. The most likely finding of any early trial is that usable ground truth does not exist. Establishing that honestly is worth more than a dashboard.

12 WHAT WE THINK SO FAR, AND WHAT WE DON'T KNOW

What we think so far, and what we don't know

What the reasoning currently supports

On the data

- Most environmental data relevant to biological risk appears to be already collected, labelled with its mechanical purpose. The data is not missing; the interpretation is.
- The biological question is rarely *what is the value* but how long has it been that way. Duration, not magnitude, separates a nuisance from a habitat.
- **TREND RETENTION, NOT SENSOR COUNT, LOOKS LIKE THE BINDING CONSTRAINT** Biology moves in seasons; ninety days of history cannot see an annual pattern.

On integration

- The integration required appears modest and read-only — thirty to eighty mapped points, not a full estate export.
- **LOCATION IS THE JOIN KEY** Reconciling "VAV-2-14" with "the store room behind the kitchen" is probably the highest-value hour on the project.
- The hardest half is not technical. It is structured observation by technicians. Sensors are the easy part; the people are the project.

On timber specifically

- Timber pest practice already reasons in conducive conditions. This is the domain where the conceptual leap is smallest — the assessment logic exists, it is simply recorded annually rather than continuously.
- Several key conducive conditions are already observable in building data. Bridging, concealment and ground clearance are not, and never will be. Any honest version of this concept keeps a technician on site.

What we do not know

- **WHETHER RESIDUAL RISK ACTUALLY HALVES** The entire economic case rests on this, and it is an assumption, not a finding. It is the first thing that should be tested and the first thing a sceptic should attack.
- **WHETHER USABLE GROUND TRUTH EXISTS** The most likely finding of any first trial is that the longitudinal records needed to validate inference were never kept in a usable form.
- **WHETHER LEAD TIME IS OPERATIONALLY USEFUL** Conditions may precede incidents by weeks, or by hours, or not reliably at all.
- **WHETHER BIOLOGY IS UNIFIABLE** Termites, decay fungi, cockroaches and rodents may share enabling conditions — or may only appear to on a slide.
- **WHETHER ANYONE WOULD BUY IT** A provider selling fewer visits at a sustained price is proposing something the market has never rewarded.
- **WHETHER THE CONCEPT SURVIVES ITS OWN FAILURE MODES** If it produces correlations that are interesting but never actionable, or actions a competent professional would have taken anyway, it should be abandoned rather than rebranded.

WHAT WOULD CHANGE OUR MIND A retrospective analysis across three to five buildings showing that environmental conditions did *not* precede known biological incidents by any useful margin would substantially weaken the thesis. So would evidence that a well-run FM team already achieves this integration informally. Both are cheap to test, and both are invited.

13 THE QUESTIONS WE ARE PUTTING TO YOU

The questions we are putting to you

These are real questions, not rhetorical ones. The author has views on some and no idea on others, and would rather be corrected now than after building something.

For facility management leaders

7. Can biological history be retrieved from one place in your estate — or is the fragmentation hypothesis confirmed the moment you try?
8. Would you grant read-only telemetry access to a pest or remediation provider? If not, what would need to change commercially, contractually or in trust before you would?
9. Who owns the biological record of your buildings, and would you notice its absence at the next handover?
10. Would you accept fewer scheduled visits in exchange for a documented risk position, or does the calendar have value as evidence in its own right?

For pest management leaders

11. Could technicians capture structured observation without adding time to the job? If not, is that a tooling problem or a standards problem?
12. What would you need to see before telling a client they need fewer visits this quarter — and could you price that conversation profitably?
13. At what portfolio size does integration cost amortise? Large accounts only, or does it work at ten sites?
14. If a competitor offered risk-triggered servicing at 40% lower annualised cost, how quickly could you respond?

For technical and scientific reviewers

15. Does risk-triggered attendance lower incident probability relative to fixed intervals — and how would that be measured without an unethical control group?
16. Are pests, microbial growth and material deterioration genuinely unifiable through shared enabling conditions, or does the framework only look unified on a slide?
17. What lead time is operationally useful, and does any combination of conditions reliably deliver it?
18. Where should the governance line sit between advisory interpretation and regulated professional judgement, and who draws it?

The question underneath all of them

19. If a building could describe its biological condition as fluently as its mechanical condition, what would change first — the technology, the contract, or the conversation?

If you read one section and want to argue with one thing, argue with the residual-risk assumption in Section 9. Everything else is arithmetic.

Buildings became observable as machines because the industry decided mechanical condition was worth measuring, agreed what to measure, and built the systems to do it. Nothing about that was inevitable. It took standards, protocols, professional norms and roughly thirty years.

Biological condition is where mechanical condition was several decades ago: understood scientifically, managed professionally, operationally fragmented. The building already generates the environmental context. Skilled professionals already generate the observations. The methods for connecting them exist and are already applied to adjacent variables. The missing element is not technology. It is a shared operational model, a common data structure, and an agreement that biological condition is something buildings should describe about themselves.

None of this replaces the people. The most sophisticated inference layer imaginable would still be less useful than a technician who has walked the same site for six years and can tell, from the smell of a plant room in August, that something has changed. The ambition is smaller and more respectful than replacement: give that person a memory that outlasts their tenure, a record that survives the contract, and a way to prove to a client what they already know.

Buildings are mechanical systems. They are also dynamic biological environments, occupied by organisms of several kinds, at least one of which pays the invoices.

That proposition is now testable. It should be tested.

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Status note: this is an open concept paper, not a product description, a service offer or a validated method. "Biological Infrastructure Intelligence" and "Biological Pressure" are proposed conceptual terms requiring literature collision checks and empirical validation before being treated as established. Cost figures in Section 9 are illustrative models built on stated assumptions, not measured results. Beacon Bio is the vehicle through which these questions are being explored; nothing here should be read as a claim that the concept has been implemented.