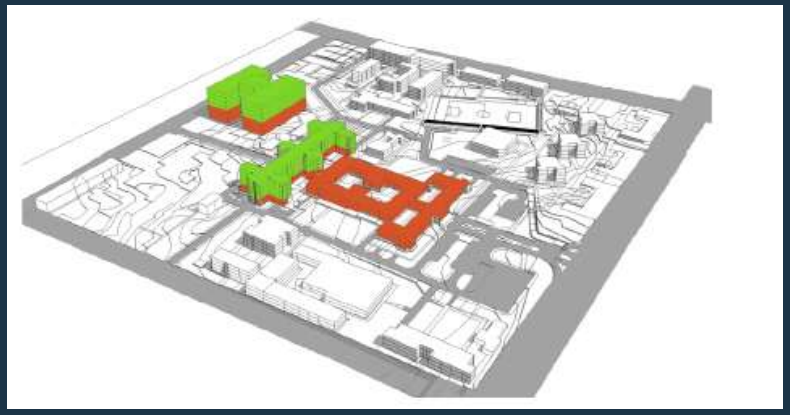
DOCTORAL DEFENSE

Adaptable and Flexible Healthcare Infrastructure

The RAF(+I) Framework for Post-Conflict Healthcare Facilities in Tigray, Ethiopia



Ayder Comprehensive Specialized Hospital — campus massing study

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Università Iuav di Venezia · School of Doctorate in Architecture, City and Design · May 2026

The Concept

Healthcare facilities in Tigray must be read as layered socio-technical assets — not as isolated buildings.

What it matters

Opening or reopening does not restore dependable capacity. The thesis separates usable clinical capacity from apparent function.

What it adds

RAF(+I) connects built-asset layers, serviceability, evidence limits, and attribution control in one assessment logic.

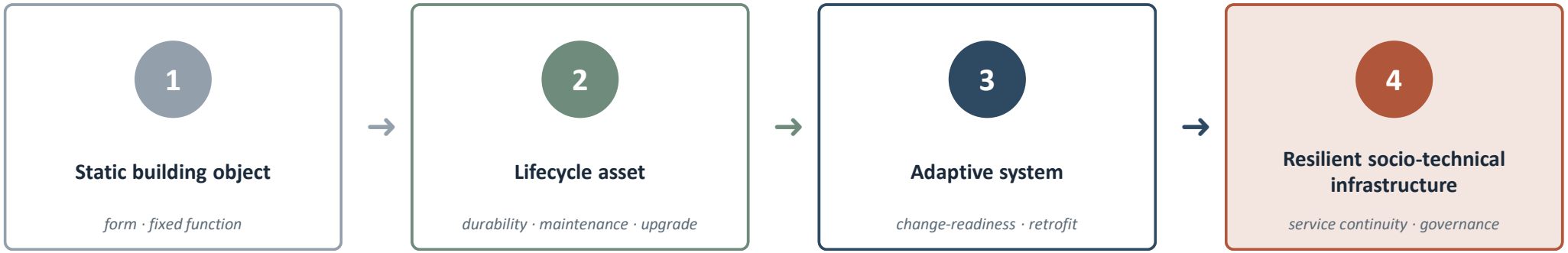
What it changes

Delivery shifts from one-off construction toward performance-led lifecycle upgrading and threshold-based intervention.

Functional breakdown = the cumulative loss of usable clinical capacity.

From static buildings to resilient infrastructure

Built-environment research increasingly treats buildings as long-life assets exposed to uncertainty, technological change, and shifting performance demands.



The thesis enters this trajectory precisely where design-for-change becomes inseparable from service continuity under constraint.

The translation gap

Global adaptability and flexibility frameworks assume enabling systems that are uneven, fragile, or absent in constrained post-conflict settings.

Common high-resource assumptions

- Stable utilities and service infrastructure
- Reliable maintenance, spares, and technical labor
- Complete documentation and asset records
- Predictable financing and procurement
- Stable governance and decision routines

vs

Constrained realities in post-conflict settings

- Interrupted lifelines and support systems
- Weak repair ecology and missing spares
- Incomplete records and configuration drift
- Procurement uncertainty, limited upgrade capacity
- Disrupted governance and decision routines

Research gap translate adaptability and flexibility concepts into disrupted, evidence-light settings without losing architectural rigor.

Tigray and the health-service hierarchy

Tigray administrative and territorial setting

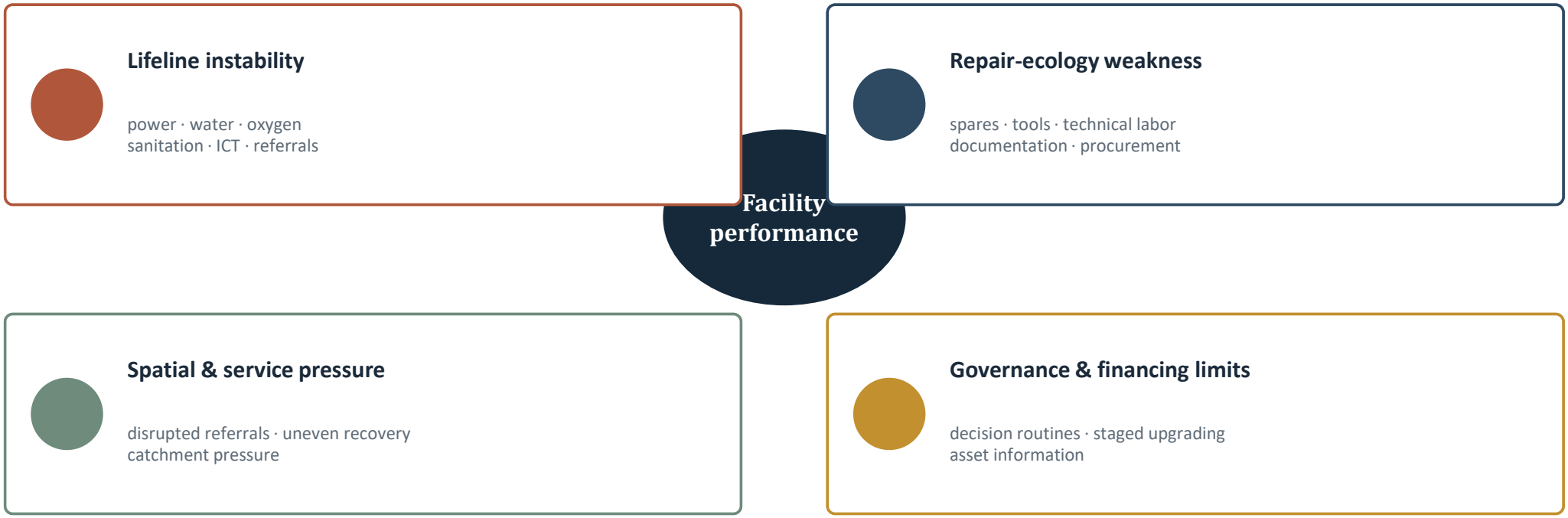
Tigray is interpreted as a service environment, not only as a geographic location.

- **5** **Comprehensive Specialized Hospital** · *apex referral*
- **4** **General Hospital** · *secondary referral*
- **3** **Primary Hospital** · *first escalation*
- **2** **Health Center** · *primary-care gatekeeping*
- **1** **Health Post** · *community access*

Cross-tier stress matters: failure or partial operation at one level redistributes pressure across the whole service network.

Tigray as an operating constraint field

Context is not a backdrop — it is an operating condition that activates, limits, or disables built assets.



Facility performance is shaped by physical condition and by the support systems that make clinical use possible.

Problem statement and research gap

Core problem

Facilities must sustain essential services while lifelines, staffing, referrals, maintenance, procurement, and records remain unstable.

Resulting mismatch

Layout and circulation rigidity · weak adjacency and zoning · serviceability gaps · patchwork additions · reduced staged-upgrade capacity.

Research gap

A context-fit architectural evaluation frame to diagnose rigidity, trace incremental evolution, separate external from building-driven constraints, and make change-readiness visible.

Much of the stock was conceived, delivered, or expanded around steady-state assumptions; actual operation is shaped by disruption, stalled development, and irregular service provision.

Aim, questions, and claim boundary

Aim Develop and empirically test an architecture-specific RAF(+I) framework for evaluating healthcare facilities in Tigray under uncertainty.

RQ1 · Diagnosis

How did standardized prototypes contribute to rigidity and loss of usable clinical capacity?

RQ2 · Evaluation method

How can RAF(+I) become an evidence-light matrix of criteria and observable indicators?

RQ3 · Design strategy

Which design, technical, and upgrading paths reduce rigidity, lock-in, and serviceability constraints?

RQ4 · Governance

Which guidelines, procurement, maintenance, and governance recommendations support RAF(+I)-based development?

Claim boundary evidence-bounded architectural interpretation — no direct clinical-outcome measurement, no full health-system causality, no statistical generalization across all regional facilities.

09 CONCEPTUAL FRAMEWORK

Core thesis argument

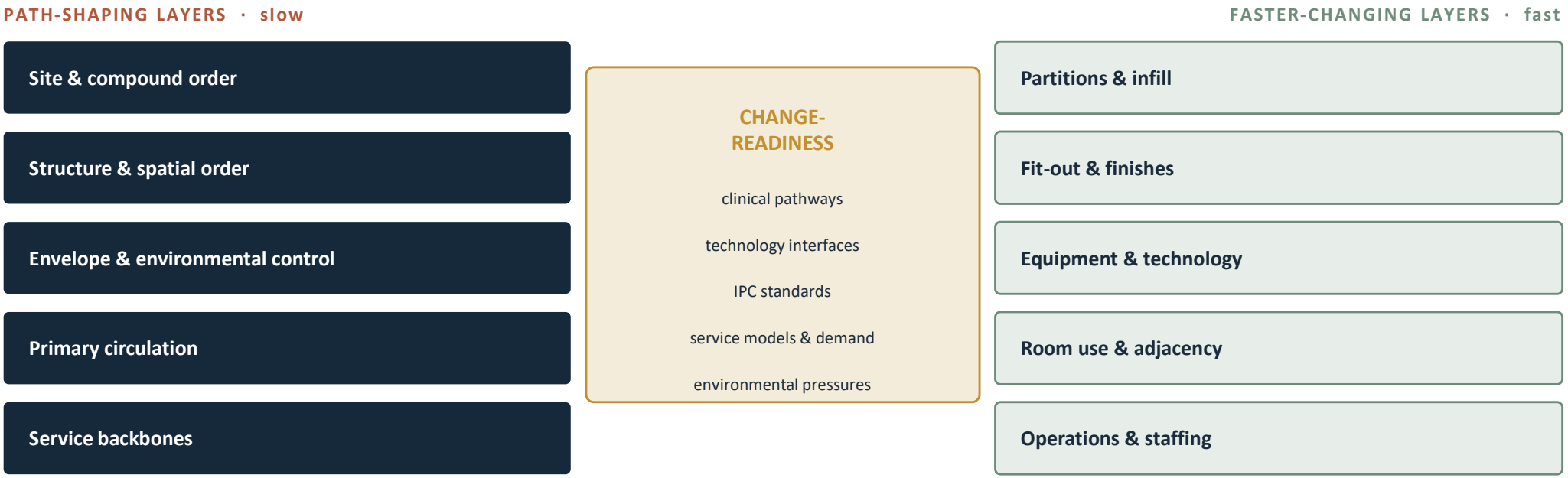
Healthcare facilities in Tigray fail, survive, and recover through the interaction of built-asset layers and operating constraints.

1. Delivery-first provision weakly protected long-term change capacity.
2. Inherited layouts, retained cores, serviceability gaps, and support-space deficits became embedded in path-shaping layers.
3. Acute shocks and chronic stressors exposed and amplified these weaknesses.
4. Continued operation often reflected coping and workaround dependence — not reliable resilience.
5. **Functional breakdown emerged as the cumulative loss of usable clinical capacity across architectural, technical, and institutional layers.**

RAF(+I) evaluates whether facilities can retain, adapt, reconfigure, and incrementally improve usable clinical capacity under constraint.

Hospitals as evolving systems

Hospitals are long-life assets embedded in short-cycle clinical, technological, environmental, and organizational change.



Design-for-change protects path-shaping layers while keeping faster-changing layers accessible for repair, reconfiguration, and staged upgrading.

RAF(+I): the evaluative lens

RAF(+I) distinguishes coping from real change-readiness.

R — Resilience

Retain or recover usable clinical capacity under disturbance.

A — Adaptability

Accommodate substantial functional or spatial change over time.

F — Flexibility

Lower-friction reconfiguration within the existing operational boundary.

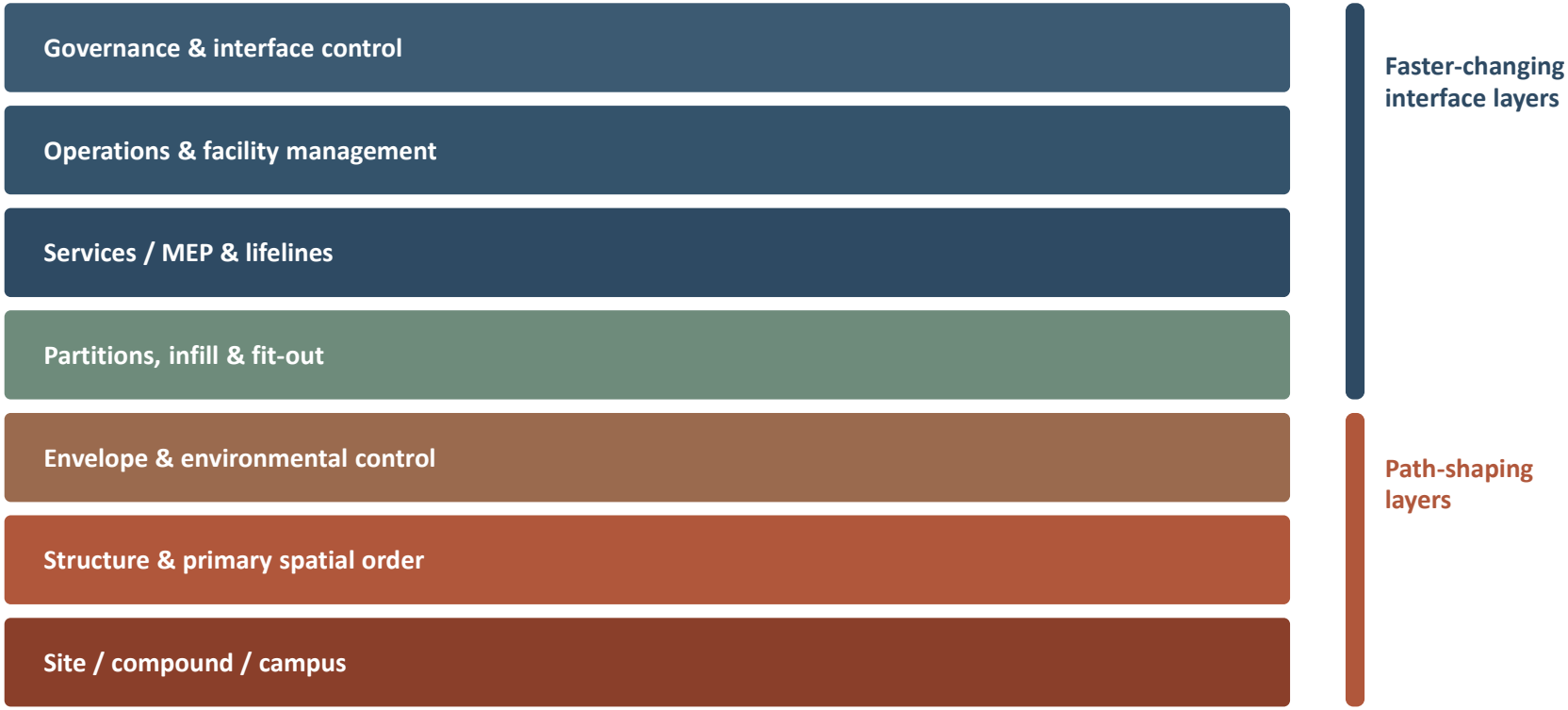
+I — Incrementalism

Governed staged upgrading — not opportunistic accretion.

Analytical question: does continued operation reflect built-environment capability — or only coping under constraint?

The facility as a layered socio-technical asset

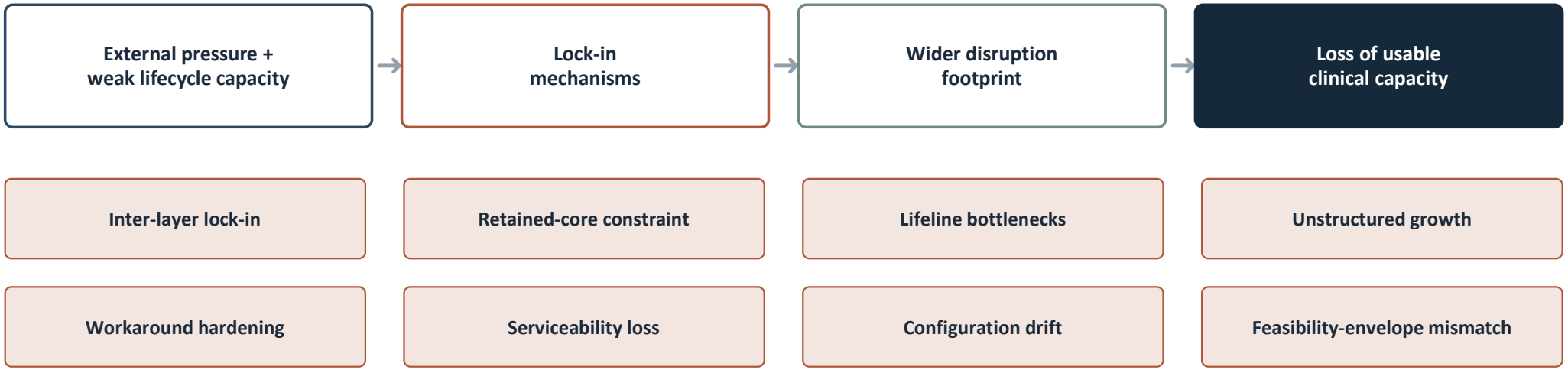
Each facility is assessed through architectural, technical, operational, and governance layers.



Analytical purpose: identify fixed constraints, remaining adaptation potential, and the interfaces where built form, services, and operations interact.

Lock-in mechanisms and functional breakdown

Functional breakdown emerges through socio-technical mechanisms — not single causes.



These mechanisms explain how external pressures become facility-level loss of usable capacity.

Layered RAF(+I) interpretation model

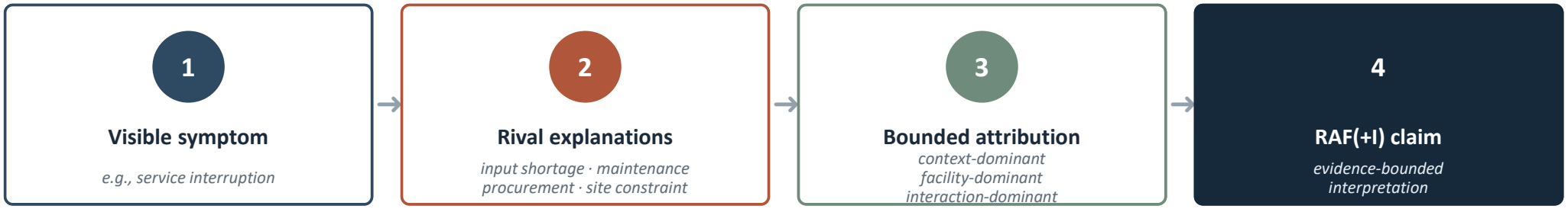
The model translates context into bounded, facility-scale RAF(+I) interpretation.

1	**Operating envelope**	National baseline → regional layer → service-delivery layer → macro constraint field
2	**Facility signatures**	Crowding · closed rooms · patch repairs · improvised routing · service interruptions
3	**Built-asset mediation**	Site / compound → structure / envelope / infill / services → operations / governance
4	**Attribution control**	Observable signature → built-asset mediation → bounded claim

Context is translated into facility claims through signatures, mediation, and attribution control.

Attribution control: from symptom to RAF(+I) claim

Attribution control prevents a direct jump from visible symptom to architectural claim.



Worked example: grid failure + inaccessible backup-service routes → an external shock becomes a wider clinical shutdown.

Outcome: an evidence-bounded RAF(+I) interpretation and design guidance — never a symptom read directly as architectural failure.

Research design logic

Pragmatic, explanatory-sequential, mixed-method design — method follows the problem.

1. **Pragmatic**
   method follows the problem
2. **Abductive**
   framework ↔ evidence
3. **Explanatory**
   diagnostic → qualitative explanation
4. **Evidence-governed**
   scores justified, capped, or NS
5. **Attribution-controlled**
   visible conditions tested against rivals

Research sequence: diagnostic profile → mechanism explanation → cross-case synthesis → design & governance implications

Phased study architecture

Phase I

Diagnostic & macro baseline

- system baseline · operability profile
- macro constraint field · scenario logic
- initial RAF(+I) profiles

→

Phase II

Case-study diagnosis

- deep-dive cases · evolution episodes
- constraint trajectories · service traces
- facility RAF(+I) profiles

→

Phase III

Cross-case synthesis & translation

- cross-case mechanisms · RAF(+I) refinement
- no-regret priorities · threshold strategy
- design & governance guidance

Analytical movement: context baseline → diagnostic signal → facility mechanism → bounded synthesis → implementation guidance

Evidence architecture under uncertainty

RAF(+I) is assessed as observed capacity under constraint — not abstract design potential.

E1	E2	E3a	E3b	E4
Observation / measurement	Longitudinal imagery	Reconstructed plans	Official records	Stakeholder accounts

Deep-dive explanatory cases

evolution · lock-in · rival explanations · facility RAF(+I) profiles

Bounded morphology layer

trajectory calibration · plausibility checks · attribution boundaries

Missing as-builts, service records, and change logs limit evidence — and themselves weaken repair, service integration, and staged change.

RAF(+I) evaluative matrix and evidence logic

The matrix converts RAF(+I) into auditable architectural assessment.

Layer	R	A	F	+I
Site	●	●	●	●
Structure	●	●	●	●
Envelope	●	●	●	●
Infill	●	●	●	●
Services	●	●	●	●
Operations	●	●	●	●
Governance	●	●	●	●

Evidence controls

confidence grades · NS / IE / NA flags · score-capping under thin evidence

Output logic

layer profiles → domain profiles → binding constraints → confidence flags → bounded diagnosis

Reporting principle: diagnostic profiles, not a single headline score.

Case portfolio and selection rationale

A tier-spanning service network — selected for controlled variation and evidentiary defensibility.

	Facility	Network role	Setting
C1	**Ayder CSH**	Apex referral	Urban
C2	**Adigrat GH**	Secondary referral	Urban
C3	**Yechila PH**	First escalation	Town / peri-urban
C4	**Gerhu Sernay HC**	Primary-care gatekeeping	Town / peri-urban
C5	**Lugda HP**	Community access	Rural

Selection logic: tier role → operating variation → traceable evolution → evidence feasibility → common RAF(+I) protocol

National and regional baseline

The baseline establishes the operating envelope for facility-scale interpretation.

National baseline — inherited delivery logic

- uneven territorial development
- higher-order service concentration
- standardized typologies and prototypes
- delivery-first financing / procurement
- maintenance debt and weak stewardship

Regional baseline — Tigray feasibility conditions

- settlement dispersion & rural access friction
- corridor dependence & referral vulnerability
- disrupted utilities, workforce, supplies
- uneven service reactivation after conflict
- climatic & microclimatic variability

HeRAMS baseline 853 assessed health-service delivery units · May–June 2023 (WHO)

0%	92%	8%
fully functional	partially functioning	non-functioning

Operability beyond physical condition

Operability is an achieved condition — not a formal status label.

Activated

lifelines · staffing · supplies · referrals

Operated

continuity · safety · service scope

Maintained

repair access · spares · tools · records

Adapted

no unsafe downtime · no new lock-in

Macro constraint field

lifeline systems · workforce capacity · repair latency · lifecycle control · access & referral pressure

Scenario regimes

stabilization · chronic stress · shock dominance · spatially uneven recovery

Visible repair or reopening may restore minimum usability without restoring dependable capability.

Layer susceptibility and RAF(+I) implications

Where does functional breakdown become visible first?

1

Threshold

intake · waiting · privacy
sanitation · filtering

2

Circulation

compound routes
internal transfer paths

3

Support depth

MEP · utilities · storage
maintenance areas

4

Environmental operability

envelope · drainage · ventilation
shading · edge conditions

5

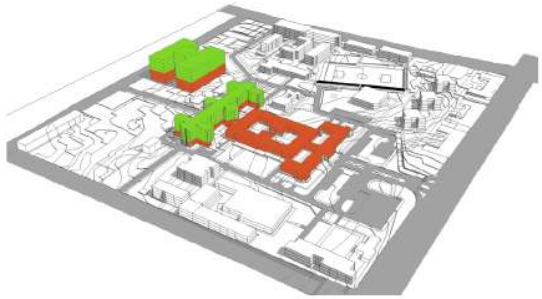
Change-readiness

site order · reserve · service reach
documentation

Visible breakdown appears at interfaces; the causes often sit deeper — in path-shaping layers and serviceability depth.

Case evidence — Ayder and the reserve-land paradox

Visible land did not automatically convert into usable adaptive capacity.



Campus massing & primary platforms

Campus evolution sequence (2008→)

Campus organization & circulation

Reserve land becomes adaptive capacity only when access, services, adjacency, phasing, and clinical-interface control are secured.

Bounded claim: morphology establishes growth accumulation and campus-ordering drift; internal service integration still requires facility-level evidence.

Case evidence — operability signatures

The most persistent constraints appear where tertiary load, service continuity, and retrofit capacity intersect.

Clinical crowding & threshold occupation

Environmental exposure, waiting conditions & improvised shading

Persistent operability signatures

1. **Acute-care flow control**
2. **WASH & IPC continuity**
3. **Vertical and dirty–clean logistics**
4. **Service retrofit & technology absorption**
5. **Campus overflow & growth misalignment**

Continued operation can mask reliance on manual workarounds, threshold occupation, and fragile serviceability.

Evolution trajectories across the portfolio

Four trajectories narrow capacity over time.

1

Reserve-land paradox

visible land, limited adaptability

Representative case: **Ayder**

2

Retained-core lock-in

old core governs later change

Representative case: **Adigrat / Yechila**

3

Fragmented accretion

visible improvement, weak integration

Representative case: **Gerhu Sernay**

4

Threshold-dependent platform

minimum continuity near breakdown

Representative case: **Lugda**

Change has strategic value only when it preserves future capability.

Cross-case mechanisms and explanatory patterns

Facilities may remain operational while becoming harder to repair, upgrade, reorganize, or adapt.

Embedded lock-in

- early embedded mismatch
- retained-core lock-in
- serviceability-depth constraint

Operational coping

- threshold / support-space fragility
- workaround-based continuity
- unguided incremental growth

Repair & governance limits

- pressure transfer across tiers
- weak repair ecology
- documentation-continuity weakness

Synthesis: continued operation ≠ reliable capability. RAF(+I) improves when short-term continuity preserves or strengthens future change capacity.

RAF(+I) refined by the evidence

Evidence-based refinement of the four constructs.

Resilience ≠ continued operation alone

Adaptability ≠ visible expansion alone

Flexibility ≠ improvised coping alone

Incrementalism ≠ additive or phased work alone

Cross-cutting refinement: stronger design discipline for path-shaping layers; controlled change-tolerance for faster-changing layers.

Boundary condition: continued service, visible activity, and physical change all require verification before being read as RAF(+I) capacity.

Answers to the research questions

RQ1 Prototype inheritance produced rigidity when early misfits became embedded in path-shaping layers.

RQ2 RAF(+I) became a context-fit matrix for evidence-bounded architectural assessment.

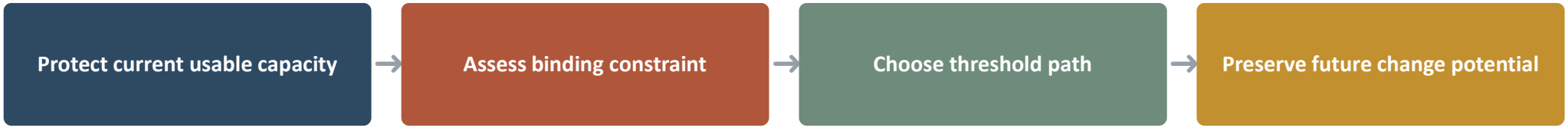
RQ3 Intervention should follow threshold judgment: upgrade, reorganize, or replace.

RQ4 Delivery should shift from construction events toward performance-led lifecycle management.

Integrated answer: functional breakdown is cumulative; RAF(+I) links physical-asset change to the capacity to plan, restore, adapt, and manage facilities over time.

Design strategy: threshold judgment

The design response is a structured decision path for constrained action — not a universal prototype.



Upgrade

when serviceability and spatial order can be recovered

Reorganize

when internal relationships and flows need restructuring

Replace / redevelop

when continued patching deepens dysfunction

Strategic premise: protect current usable clinical capacity while preserving the conditions for future change.

Implementation pathway and governance shift

1 Immediate stabilization

- protect operability
- reduce unsafe workarounds
- stabilize critical lifelines

→

2 Phased refurbishment

- correct serviceability constraints
- improve circulation & support depth
- recover documentation

→

3 Long-term reorganization

- reorganize · redevelop · replace
- when continued patching is untenable
- sequence by threshold judgment

Governance shift: delivery-first construction → performance-led lifecycle upgrading

- **procurement alignment**
- **maintenance continuity**
- **asset-information discipline**
- **change-control routines**

STRATEGY & CONTRIBUTION

Contribution, transferability, and final claim

The thesis explains how healthcare facilities in Tigray fail, survive, and recover as layered socio-technical assets under severe constraint.

Theoretical
RAF(+I) for high-shock, low-resource, evidence-light environments

Methodological
Evidence-bounded architectural judgment under uncertainty

Empirical
Facility-scale evidence across Tigray's healthcare hierarchy

Practical / governance
Threshold-based intervention and lifecycle upgrading

Transferable value: layered asset reading → attribution control → threshold judgment → performance-led lifecycle upgrading

Design-for-change protects future capability under instability.

Thank you · Daniel Semunugus Negese · Università Iuav di Venezia