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τ for WASH in Health Facilities, Schools, Camps, and Climate-Vulnerable Settlements

Conditional public-good pathway for WASH in Health Facilities, Schools, Camps, and Climate-Vulnerable Settlements

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Thorsten Fuchs · Anna-Sophie Fuchs

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This briefing is a conditional public-good impact dossier released as a publication-ready PDF artifact on 2026-05-02. Publication-ready means the dossier is downloadable, internally consistent, and claim-safe. It does not validate the τ -framework, does not claim deployment readiness, and does not assert that the described domain system already exists. It maps a plausible impact pathway if the relevant upstream Results, Corpus constructions, and translation assumptions survive expert review and domain benchmarking.

What this dossier claims

- maps a conditional public-good impact pathway
- identifies upstream framework dependencies that would have to survive review
- states translation assumptions, benchmark needs, and governance guardrails

What this dossier does not claim

- does not validate the Tau framework
- does not claim that a domain system or product already exists
- does not claim deployment readiness, policy adoption, or certified impact
- does not replace independent domain review, empirical benchmarking, or governance assessment

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1 Executive Summary

This dossier evaluates the public-good opportunity of deploying the τ categorical framework as a physics-faithful operational twin for water, sanitation, and hygiene (WASH) in four of the world's most failure-prone service environments: health care facilities, schools, camps and displacement settings, and climate-vulnerable informal settlements.

The official baseline is acute. WHO and UNICEF reported in 2025 that **1.1 billion people** are served by health facilities lacking basic water service, **447 million children** lack basic drinking water at school, **3.4 billion people** lack safely managed sanitation globally, and **over 1.1 billion people** live in slums and informal settlements that are among the most climate-exposed places on earth. UNHCR's 2024 reporting shows that only **53% of refugees** have access to a safe household toilet — in the same period when more than 100 million people are forcibly displaced worldwide. These are not edge statistics. They are the operational reality of WASH in the settings this paper addresses.

The COVID-19 pandemic made this concrete at scale: handwashing at health facilities is foundational to infection control, and the absence of basic WASH infrastructure at clinics and hospitals directly amplifies disease transmission. The WHO/UNICEF 2020 global baseline for health facility WASH found that **1 in 4 health care facilities lacked basic water service** and **45% of facilities in least-developed countries lacked basic handwashing facilities**. Healthcare-associated infections attributable in part to WASH failures cause an estimated **1.4 million deaths per year** globally.

The τ opportunity in this cluster is not to add another monitoring dashboard. It is to ask what changes when critical-service WASH moves from fragmented, lagging, and reactive management toward a **law-faithful, bounded-error, coarse-grainable operational twin** that can predict contamination cascades, service interruptions, and compound failure pathways hours to weeks before they materialize — and translate those predictions into site-specific operational decisions.

Under the planning assumptions of this yellow paper, the gains are first-tier: fewer avoidable infections at care facilities, reduced school WASH failures and learning disruption, more effective trucked-water and sanitation operations in camps, and earlier, better-targeted response to climate-driven WASH breakdowns in vulnerable neighborhoods.

This is where τ would demonstrate whether a high-fidelity water twin can do something profoundly practical: help keep care safe, schools open, camps dignified, and vulnerable settlements healthier under growing climate and service stress.

2 Reader Stance, Scope, and Caveat Structure

2.1 Planning stance

This paper adopts a deliberate conditional stance:

1. **Assume, for planning purposes, that the strongest τ claims relevant to WASH continuity are operationally sound.**
2. **Ask what practical and public-good consequences would follow if those capabilities were integrated into health facilities, schools, camps, and climate-vulnerable settlements.**
3. **Separate clearly:** what official institutions already know and already want; what τ would newly provide under the assumption; and what impact scenarios are reasoned planning inferences rather than official forecasts.

This is a **yellow paper**. It is assumption-led, translation-oriented, and public-good framed. It does not claim that external institutions have accepted the strongest τ assumptions. It asks what follows **if** those assumptions are true enough to matter operationally.

2.2 Scope of Paper 5

This is **Paper 5 of 5** in the τ Water, WASH, and Basin Intelligence portfolio. It focuses on:

- WASH in health care facilities — hospitals, clinics, district health centers, maternity wards, and primary-care facilities;
- WASH in schools and learning environments — drinking water, sanitation, hygiene, and menstrual health;
- WASH in camps, displacement settings, and emergency shelter systems — trucked water, storage, sanitation density, and outbreak prevention;
- WASH in slums, informal settlements, and climate-vulnerable neighborhoods — shared water points, decentralized sanitation, flood contamination, and upgrading prioritization;
- service continuity under compound stress — flood, drought, heat, outage, contamination, population surge, and outbreak conditions;
- and operational coordination between water, sanitation, hygiene, waste, power, health, and shelter systems.

2.3 Relation to the rest of the portfolio

The other four papers in the water portfolio are:

- **Paper 1:** source-water, treatment, and drinking-water quality early warning;
- **Paper 2:** distribution networks, leakage, pressure, and service continuity;
- **Paper 3:** wastewater, stormwater, sanitation, and circular reuse;
- **Paper 4:** river-basin, groundwater, drought–flood allocation, and water productivity.

This paper stays focused on the **critical-service and vulnerable-settlement layer** — the places where WASH failure has the most immediate and inequitable human consequences.

3 The Problem: Why WASH in These Settings Still Fails at Scale

3.1 The global burden in numbers

The scale of the problem is not ambiguous. WHO and UNICEF’s 2025 reporting provides the clearest official statement of where the burden stands:

- **2.1 billion people** still lack safely managed drinking water at home;
- **3.4 billion people** lack safely managed sanitation;
- **1.7 billion people** lack basic hygiene services;
- and WASH failures are associated with approximately **1.4 million deaths per year**, primarily from diarrhoeal disease, cholera, and related infections.¹²³

¹WHO. “1 in 4 people globally still lack access to safe drinking water – WHO, UNICEF.” 26 August 2025. <https://www.who.int/news/item/26-08-2025-1-in-4-people-globally-still-lack-access-to-safe-drinking-water---who--unicef>

²WHO. “Sanitation” fact sheet. 22 March 2024. <https://www.who.int/news-room/fact-sheets/detail/sanitation>

³WHO Global Health Observatory. “Water, sanitation and hygiene: burden of disease.” <https://www.who.int/data/gho/data/themes/topics/water-sanitation-and-hygiene-burden-of-disease>

But the headline numbers obscure the structural concentration of the burden. The hardest failures cluster precisely in the settings this paper addresses — the places where WASH is simultaneously most critical and most fragile.

3.2 Health care facilities: the missing critical link in infection control

WHO and UNICEF’s 2025 health facility WASH report is unequivocal. In 2023:

- **1.1 billion people** were served by health care facilities lacking basic water service;
- **3 billion** were served by facilities lacking basic sanitation;
- **1.7 billion** were served by facilities lacking basic hygiene;
- and **2.8 billion** were served by facilities lacking basic waste services.⁴

The 2020 global baseline — which provided the most granular country-level picture — found that in least-developed countries, **1 in 4 facilities lacked basic water service** and **45% lacked basic handwashing facilities**.⁵ Sub-Saharan Africa carries the heaviest load: in many countries, 2 in 3 health facilities lack adequate sanitation.

This is not merely an infrastructure gap. It is a patient safety crisis. Healthcare-associated infections (HAIs) attributable in part to WASH failure cause an estimated **1.4 million deaths per year globally**, with developing-country health systems bearing a disproportionate share of that burden.⁶ The World Bank estimates WASH-linked disease costs developing countries approximately **\$260 billion per year**.⁷

COVID-19 made the mechanism explicit at global scale: without handwashing infrastructure, infection control collapses. Maternity wards without running water cannot protect mothers and newborns from sepsis. Operating theaters without reliable water and sanitation cannot be maintained. The same WHO/UNICEF 2025 reporting frames WASH, waste, and electricity in health care facilities as inseparable from climate resilience and environmental sustainability for quality care.⁸

3.3 Schools: WASH as a condition for learning, dignity, and safety

UNICEF’s 2024 data on WASH in schools show that:

- **447 million children** lacked a basic drinking-water service at school;
- **427 million** lacked basic sanitation;
- and **646 million** lacked basic hygiene.⁹

These are not abstract infrastructure statistics. School WASH is tied directly to health, attendance, dignity, menstrual hygiene management, cognitive performance, and the ability to keep schools open

⁴WHO / UNICEF. “Countries making unprecedented efforts, but billions still lack basic services in health care facilities – WHO/UNICEF new report warns.” 24 September 2025. <https://www.who.int/news/item/24-09-2025-countries-making-unprecedented-efforts-but-billions-still-lack-basic-services-in-health-care-facilities---who-unicef-new-report-warns>

⁵WHO / UNICEF. *WASH in Health Care Facilities: Global Baseline Report 2020*. World Health Organization, 2020. <https://www.who.int/publications/i/item/9789240015951>

⁶WHO. “Health care-associated infections fact sheet.” World Health Organization. https://www.who.int/gpsc/country_work/gpsc_ccisc_fact_sheet_en.pdf. See also: Allegranzi B et al. “Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis.” *Lancet* 2011; 377(9761):228–241.

⁷World Bank. *The WASH Poverty Diagnostic Initiative*. Washington, DC: World Bank. <https://www.worldbank.org/en/topic/water/publication/the-wash-poverty-diagnostic-initiative>

⁸WHO / UNICEF. *Essential services for quality care: Water, sanitation, hygiene, health care waste and electricity services in health care facilities: global progress report*. 2025. https://cdn.who.int/media/docs/default-source/wash-documents/wash-in-hcf/who_unicef_washwasteelectricityinhcglobalprogressreport2025_web.pdf

⁹UNICEF Data. “WASH in schools.” Updated 27 May 2024. <https://data.unicef.org/topic/water-and-sanitation/wash-in-schools/>

safely during outbreaks or extreme weather events. Girls are disproportionately affected: the absence of private, functional sanitation facilities is one of the documented drivers of school dropout among adolescent girls in low-income settings.

Heat events, flooding, and droughts increasingly disrupt school WASH systems that were already fragile. A school latrine flooded by monsoon rains is not just an infrastructure failure — it may mean a week of closure and a month of restored exposure to open defecation risk for hundreds of children.

3.4 Displacement and camps: where WASH fragility is most acute

UNHCR’s 2024 Global Report shows a mixed but structurally concerning picture. In 33 countries, **7.7 million people** received UNHCR-supported water and/or sanitation services. Among refugees in 35 countries, **85%** had access to basic drinking water — but only **53%** had access to a safe household toilet.¹⁰

More than 100 million people are now forcibly displaced worldwide. The largest camp operations — Cox’s Bazar in Bangladesh, Kakuma in Kenya, Zaatari in Jordan — operate at scales that rival mid-sized cities, but with WASH infrastructure that was designed as temporary and is under constant stress from weather, population fluctuation, supply chain failures, and the cumulative degradation of facilities that were never meant to last a decade.

Cholera, diphtheria, and acute watery diarrhea outbreaks in displacement settings follow predictable but poorly anticipated triggers: heavy rainfall that floods latrines and contaminates water points, heat events that accelerate pathogen growth in storage tanks, population surges that overwhelm sanitation density, and supply chain disruptions that leave chlorination gaps for days or weeks. The problem is not that these triggers are unknown — it is that the operational systems to anticipate and act on them ahead of outbreak events are not in place.

3.5 Informal settlements: 1.1 billion people at the intersection of WASH and climate risk

UN-Habitat’s World Cities Report and 2024 Annual Report document that **over 1.1 billion people** live in slums and informal settlements globally.^{11,12} These settlements are not marginal. They are the dominant urban form across much of the Global South, and they are among the places most exposed to the intersection of WASH failure and climate stress.

In informal settlements, flood risk, drainage failure, contamination, unreliable water service, and weak sanitation systems do not occur independently — they cascade. A single heavy rainfall event can simultaneously flood pit latrines, contaminate shared water points, surcharge drainage channels that run past food preparation areas, and cut off motorized water delivery for days. The tools currently available to manage this do not see these cascades as integrated physical events. They see them as separate incidents reported by different agencies in different formats.

4 Working τ Assumptions for WASH-Critical Service Systems

For this paper, the strongest relevant τ assumptions are stated explicitly as planning assumptions, not as claims about accepted science:

1. τ provides a law-faithful discrete twin of local water supply, sanitation flows, contamination

¹⁰UNHCR. *Global Report 2024*. 17 June 2025. <https://www.unhcr.org/publications/global-report-2024>

¹¹UN-Habitat. “2024 Annual Report: The housing gap is widening.” 2 June 2025. <https://unhabitat.org/news/02-jun-2025/2024-annual-report-the-housing-gap-is-widening>

¹²UN-Habitat. *World Cities Report 2024*. <https://unhabitat.org/wcr/>

transport, storm and flood intrusion, storage behavior, and basic service operations at facility-to-neighborhood scale.

2. **Precision and refinement remain structurally aligned**, allowing useful coarse-graining without the usual drift between mesh resolution and decision-relevant confidence.
3. **Critical-service WASH can be represented inside one operational world** that couples water source, treatment, distribution, sanitation, hygiene, waste, power, outage, weather, occupancy, and service demand into a single coherent state.
4. **Contamination and continuity risks can be forecast with bounded error** under both normal operating conditions and compound stress events — floods, droughts, heat, outage, population surge.
5. **Convergent operational computations stabilize finitely**, supporting trustworthy stopping rules for advisory generation, dispatch recommendations, and emergency triage.
6. **The same formal substrate can support both emergency response and long-horizon resilience planning**, without requiring separate models for different time scales.

These are strong assumptions. They are not asserted as accepted public fact. They are the planning basis for this yellow paper, and they define what τ would need to deliver to realize the scenarios described below.

5 What Changes Under the τ Assumption: From Monitoring to Continuity Management

Today, WASH in health facilities, schools, camps, and vulnerable settlements is typically managed through fragmented stacks: one dashboard for water supply, another for sanitation, another for hygiene supplies, another for health or school occupancy, another for flood alerts, another for power outages, and another for disease surveillance. That can still help. But it makes it hard to answer the questions operators actually face.

5.1 The questions operators face but cannot currently answer

- Which clinic faces the highest water-service interruption risk in the next 24 hours, and what is the most likely pathway?
- Which school should receive emergency water or handwashing reinforcement first, given tomorrow's heat forecast?
- Which camp blocks need toilet desludging action before the next rainfall event — not after the latrines are flooded?
- Which settlement zones are at greatest contamination risk when drains surcharge or network pressure drops below safe levels?
- Which limited crews, water trucks, and chlorination resources should be repositioned now, rather than after the event is underway?

These are the questions that determine whether WASH services in critical settings remain functional under stress or cascade into failures that take days to weeks to recover from. Under the strongest τ assumption, they become answerable within bounded error in near-real time.

5.2 From lagging indicators to executable continuity states

The key object is no longer a static service score or an assessment completed quarterly. It becomes a **dynamic continuity state** — a continuously updated representation of:

- source or trucked-water availability and quality risk;

- treatment performance and residual-chlorine status;
- storage levels and contamination probability;
- network pressure or local delivery conditions;
- sanitation-functionality and desludging-urgency status;
- hygiene station water availability and supply status;
- waste handling and overflow risk;
- current and forecast weather and flood stress;
- outage conditions and backup power status;
- and occupancy, service demand, and population-surge indicators.

This is the kind of object that operators at district health offices, camp management agencies, and school-system maintenance units actually need — not a report produced after the event, but a living state that drives decisions before service failure occurs.

5.3 From single-sector management to cascade management

In practice, WASH failures in these settings almost always propagate through cascades rather than occurring as isolated events. The most common cascade patterns are:

- **Flood → contamination → treatment overload → hygiene failure → outbreak risk:** a rainfall event contaminates intakes, overwhelms treatment capacity, depletes storage of treated water, and leaves handwashing stations without chlorinated supply exactly when pathogen load in the environment is highest;
- **Power outage → pumping failure → pressure loss → contamination ingress → service interruption:** particularly severe for hospitals and clinics that require continuous water supply for infection control;
- **Heat wave → demand surge → low storage → rationing → hygiene compromise:** water supply that is adequate at average demand becomes insufficient when heat drives consumption up by 40–60%;
- **Population surge in camps → sanitation overload → desludging backlog → protection and disease risk:** a sudden arrival of displaced persons exceeds latrine capacity before maintenance systems can respond.

A τ twin would matter most if it makes these cascades explicit early enough to act on them — before the cascade has run its course and the outbreak, latrine collapse, or clinic water outage has already occurred.

5.4 From generic alerts to site-specific operational playbooks

The highest-value τ output would often not be a probability score or a risk map. It would be a **site-specific, time-stamped action recommendation** tied to the current and forecast state of a specific facility or zone:

- isolate the surface intake and switch to reserve storage at Clinic X before the flood event arrives in 18 hours;
- boost chlorination at water point W-7 in Camp Block C ahead of the temperature spike forecast for tomorrow afternoon;
- deploy emergency water storage to Schools 14 and 22 in District N before the heat event;
- reschedule desludging at latrine blocks 8–12 in the northern camp sector before the monsoon rains;
- pre-position handwashing supplies at the maternity ward ahead of the planned outage window;
- or alert neighborhood upgrading coordinators that drainage capacity in Sector J will be exceeded at 60mm/hr rainfall — 12 hours before it hits.

That is the real public-good promise of a τ WASH layer: not better surveillance of failures already in progress, but better anticipation of failures not yet begun.

6 Structured Opportunity Map

6.1 Opportunity Family A — WASH in Health Care Facilities

This is the highest-stakes opportunity family in the cluster. The failure modes are well documented, the humanitarian and epidemiological consequences are severe, and the official institutional recognition of the gap is explicit.

Key sub-opportunities:

- **Source and treatment resilience** for district hospitals and rural clinics, including contamination early warning and backup supply activation;
- **24/7 service continuity** for maternity wards, neonatal units, dialysis facilities, operating theaters, and other infection-prevention-critical care environments;
- **Safe sanitation, waste, and hygiene continuity** under compound stress — flood, outage, heat, drought, or supply chain disruption;
- **Climate-resilient WASH retrofitting and capital investment sequencing** — which facilities should be prioritized for storage, treatment upgrade, or borehole protection given their hazard exposure and patient risk profile;
- and **integrated WASH-power-service continuity planning**, so that facility managers do not learn of a water supply interruption only after it has compromised sterile fields or infection control procedures.

The WHO/UNICEF 2025 report makes this one of the most obvious first-wave τ application areas.¹³¹⁴ The combination of well-defined facility footprints, high patient sensitivity, and increasingly climate-stressed water supply in low-income countries creates a clear case for physics-faithful prediction.

6.2 Opportunity Family B — WASH in Schools and Learning Environments

School WASH is distinctive because the consequences of failure are both health-related and educational. Water service disruptions do not just cause thirst — they close schools, trigger disease absences, and deny girls dignified sanitation access that is a precondition for attendance.

Key sub-opportunities:

- **School drinking-water continuity** — predicting and preventing point-of-use quality failures and supply interruptions before they affect children;
- **Toilets and handwashing reliability** — especially during disease outbreaks, flood events, and heat periods when demand and vulnerability are simultaneously elevated;
- **Menstrual hygiene management** — ensuring water and private sanitation availability for adolescent girls throughout the school year;
- **Flood and heat WASH continuity for school operations** — including flood-proofing of sanitation facilities and emergency water supply for heat events;

¹³WHO / UNICEF. “Countries making unprecedented efforts, but billions still lack basic services in health care facilities – WHO/UNICEF new report warns.” 24 September 2025. <https://www.who.int/news/item/24-09-2025-countries-making-unprecedented-efforts-but-billions-still-lack-basic-services-in-health-care-facilities---who-unicef-new-report-warns>

¹⁴WHO / UNICEF. *Essential services for quality care: Water, sanitation, hygiene, health care waste and electricity services in health care facilities: global progress report.* 2025. https://cdn.who.int/media/docs/default-source/wash-documents/wash-in-hcf/who_unicef_washwasteelectricityinhcfglobalprogressreport2025_web.pdf

- and **school-by-school risk-based upgrading** — using τ -derived hazard and service-continuity scores to sequence capital investment where protection need is highest.

Because school WASH links directly to learning, dignity, gender equity, and child health, it is one of the most socially legible τ opportunities in the entire portfolio.¹⁵

6.3 Opportunity Family C — Camps, Displacement Settings, and Emergency Shelter Systems

Camp WASH is operationally intensive, logistically constrained, and chronically under-resourced relative to the scale of need. The operational complexity is high: trucked-water schedules, storage tank management, chlorination, latrine siting, desludging frequency, queue management, and outbreak surveillance all have to work together in an environment where population, topography, rainfall, and supply chains change unpredictably.

Key sub-opportunities:

- **Trucked-water optimization** — routing, scheduling, and storage deployment under dynamic demand and access constraints;
- **Storage, chlorination, and queue management** — predicting when tank levels and residual chlorine will fall below safe thresholds given temperature, demand, and supply variability;
- **Toilet siting and desludging** under changing occupancy and seasonal rainfall — particularly for the pre-monsoon period when desludging backlogs are most dangerous;
- **Outbreak-sensitive WASH triage** — identifying which blocks, sectors, or water-point catchments are at highest cholera or diarrhea risk given current WASH and environmental conditions;
- and **combined WASH-protection-health continuity** in camps and transit sites, ensuring that operational decisions about water, sanitation, and hygiene are made within a single frame that also accounts for health surveillance and protection indicators.

6.4 Opportunity Family D — Climate-Vulnerable Settlements and Urban Informality

This family requires a different operational mode than facilities and camps — the “facilities” are often informal, unmapped, and unmetered, and the “management” is often absent or fragmented across multiple neighborhood-level actors.

Key sub-opportunities:

- **Flood contamination alerting** for informal neighborhoods — identifying which shared water points, micro-piped systems, and low-lying latrines are at contamination risk before flooding occurs;
- **Shared-water-point reliability** — predicting supply interruptions, quality failures, and queue burden under drought, heat, and network stress;
- **Decentralized sanitation and drainage continuity** — managing pit latrine overflow risk, drainage surcharge, and settlement-level contamination spread under rainfall;
- **Hotspot mapping** for heat/drought/service stress — identifying which sub-neighborhoods face compounding WASH vulnerability and should be prioritized for emergency response or upgrading;
- and **WASH-prioritized slum upgrading sequences** — using τ -derived resilience scores to guide capital investment decisions made by municipal governments and development finance institutions.

¹⁵UNICEF Data. “WASH in schools.” Updated 27 May 2024. <https://data.unicef.org/topic/water-and-sanitation/wash-in-schools/>

6.5 Opportunity Family E — Cross-Domain Service Continuity and Outbreak Prevention

This is the integrating family across the other four. It addresses the coordination problem that arises when health facilities, schools, camps, and neighborhoods are part of the same disease transmission environment and the same emergency response system.

Key sub-opportunities:

- **Cholera and diarrhoeal outbreak risk prevention** — coupling WASH state with disease surveillance to identify and act on early warning signals before outbreaks are confirmed;
- **Climate-sensitive WASH emergency planning** — using seasonal and multi-week climate forecasts to pre-position resources, conduct preventive maintenance, and adjust operating protocols;
- **WASH-health-school coordination** — ensuring that health and education authorities see the same WASH risk state and can coordinate responses across sectors;
- and **resource allocation across critical sites under scarcity** — when there are more high-risk facilities, camps, and neighborhoods than there are crews, trucks, and treatment inputs to serve them, τ can support principled prioritization rather than ad hoc triage.

7 Competitive Landscape: What Exists Today and Where the Gaps Are

The existing tool ecosystem for WASH in health facilities, schools, camps, and vulnerable settlements is assessment-oriented rather than predictive, and single-sector rather than integrated. The following five widely used tools define the current state of the art and the gap that τ addresses.

7.1 WHO WASH-FIT (Water and Sanitation for Health Facility Improvement Tool)

WASH-FIT is WHO's primary framework for WASH assessment and improvement planning in health care facilities. It provides a structured assessment protocol covering water, sanitation, hygiene, waste management, and environmental cleaning. It has been deployed in dozens of countries and generates facility-level improvement plans.

Its limitations are structural: WASH-FIT is assessment-based and retrospective. It tells a facility where it stands at the time of assessment; it does not predict when service continuity will be compromised or how WASH state will respond to a flood, drought, or outage event. It is not climate-aware, not predictive, and does not couple facility WASH state to the surrounding hydrological or weather environment. The improvement plans it generates are valuable for capital planning but do not support operational decision-making.

A τ WASH layer would not replace WASH-FIT — it would extend it into the operational and climate-resilience dimension that WASH-FIT explicitly does not cover.

7.2 JMP (WHO/UNICEF Joint Monitoring Programme)

JMP is the global WASH monitoring baseline — the system by which WHO and UNICEF produce country-level estimates of access to water, sanitation, and hygiene services across households, health facilities, and schools. JMP data are the authoritative source for global advocacy and policy, and they have been instrumental in documenting the severity of the gap this paper addresses.

JMP's limitations are by design: it is a monitoring system, not an operational tool. Its data are survey-based, retrospective, and aggregated at national and sub-national scales. It does not generate real-time or predictive facility-level risk estimates, and it is not designed to support operational

WASH management. JMP establishes the “why” — the scale and severity of the problem — but not the “how” of day-to-day operational response.

7.3 Akvo FLOW / Akvo CADDISFLY

Akvo FLOW is a mobile data collection platform widely used for WASH monitoring in the field, including water point mapping, asset condition surveys, and monitoring of WASH programs. Akvo CADDISFLY is a companion water quality testing tool. Together they provide an important field data collection and management layer for WASH programs in low-income settings.

Their limitations are also by design: they are field monitoring and data management tools, not physics models. They collect and organize field observations — they do not model water system behavior, predict contamination events, forecast service continuity under stress, or couple WASH infrastructure state to weather or climate inputs. They are necessary infrastructure for WASH programs, but they do not provide the predictive intelligence this paper addresses.

7.4 UNICEF WASH Cluster Information Management

In humanitarian settings, UNICEF leads the Global WASH Cluster, which coordinates the operational response of dozens of agencies in displacement and emergency settings. The Cluster’s information management system tracks WASH service coverage, cluster partner activities, supply pipeline, and operational gaps across emergency operations.

Its limitations are operational-coordination rather than physics-based: the Cluster system is designed for humanitarian logistics coordination, not for physics-faithful prediction of service continuity or contamination risk. It does not model water system behavior under climate stress, predict latrine overflow probability ahead of rainfall, or optimize trucked-water routing under dynamic demand. It is essential for coordination but does not provide the predictive layer that would allow early action before failures occur.

7.5 WaterAid WASH Systems Strengthening and IRC WASH Systems

WaterAid and the IRC (International Water and Sanitation Centre) both provide sector-level planning and monitoring frameworks under the WASH systems strengthening approach. These frameworks emphasize the enabling environment, financing, governance, accountability, and sustainability dimensions of WASH service delivery — the conditions under which WASH services can be maintained over time.

These are valuable planning and policy tools. They are not quantitative physics models. They do not generate operational predictions of service continuity, contamination risk, or climate-driven failure pathways. They address the systemic and institutional conditions for WASH at a level of abstraction that is complementary to, rather than competitive with, a τ operational twin.

7.6 The gap τ addresses

Taken together, the existing tool ecosystem is strong on assessment, monitoring, coordination, and systemic planning — and absent on physics-faithful, climate-aware, predictive, operational intelligence. No existing tool couples the physical dynamics of water supply, sanitation, hygiene, weather, and contamination into a single bounded-error operational twin that can answer the questions operators face in real time. That is the gap τ addresses.

8 Evidence and Translation Ladder

A credible deployment pathway for τ WASH in critical-service and vulnerable-settlement settings should progress through four stages, with each stage building on evidence from the previous.

8.1 Stage 1 — Shadow-mode advisory pilots (Years 1–2)

Deploy τ in shadow mode alongside existing tools in selected geographies:

- district hospitals and clinics in flood- and drought-exposed regions;
- school systems in heat- and flood-prone districts;
- camp or settlement WASH operations with monsoon or seasonal stress cycles;
- and climate-vulnerable urban neighborhoods in flood-prone cities.

Focus initially on:

- hazard-linked continuity warnings — alerting facility managers and camp coordinators when WASH systems face elevated failure probability ahead of weather events;
- water-quality risk flags — identifying when contamination risk is elevated at specific sources, treatment steps, or distribution points;
- storage and trucking prioritization — recommending preemptive reallocation of scarce water resources before demand peaks;
- and sanitation and hygiene failure forecasts — predicting when toilet, handwashing, or desludging systems will become non-functional under forecast conditions.

The primary output of Stage 1 is a validated track record: how often did the τ advisory correctly anticipate events that existing monitoring missed, and how often were false alarms generated?

8.2 Stage 2 — Operator support and triage integration (Years 2–4)

Integrate τ outputs into operational workflows:

- clinic and district health office dashboards, so that facility managers and district health officers see WASH risk state alongside health outcome indicators;
- education facility maintenance and school health systems, so that WASH continuity alerts trigger maintenance action rather than post-event remediation;
- camp coordination and humanitarian cluster operations, so that τ -derived contamination and overflow risk informs trucking, desludging, and chlorination scheduling;
- and municipal or slum-upgrading control rooms, so that climate-driven WASH risks in informal settlements are visible to the teams responsible for emergency response and upgrading programs.

8.3 Stage 3 — Resource optimization and resilience planning (Years 3–6)

Use τ to drive capital and operational decisions:

- climate-resilient WASH investment prioritization — which facilities, schools, and neighborhood zones should receive storage upgrades, borehole protection, or treatment improvements given their hazard exposure and patient/student risk profile;
- preventive maintenance scheduling — shifting from fixed-cycle maintenance to condition-and-forecast-based scheduling that acts before failure rather than after;
- decentralized backup and storage design — using τ failure probability maps to size and locate emergency water storage, backup chlorination, and pit desludging capacity;

- and climate-resilient WASH planning — embedding τ risk profiles into national facility WASH plans, humanitarian response plans, and urban resilience strategies.

8.4 Stage 4 — Standards and system-level embedding (Years 5–10)

If the operational value from Stages 1–3 is demonstrated, the next step is institutional embedding:

- incorporating τ -style bounded-error WASH continuity twins into routine public-health facility planning, WASH-FIT assessment follow-through, humanitarian cluster operations, and urban resilience planning;
- developing standards for physics-faithful WASH intelligence in critical-service settings, analogous to how flood modeling standards evolved for disaster risk management;
- and linking τ risk profiles to WASH finance mechanisms — conditional grants, service contracts, and performance-based financing that rewards verified service continuity rather than infrastructure existence.

9 Case Studies: Where the Stakes Are Highest

9.1 Case Study 1: Cox’s Bazar Rohingya Refugee Camps — The World’s Largest Camp WASH Operation Under Climate Stress

Scale and context. Cox’s Bazar in Bangladesh hosts more than 900,000 Rohingya refugees across 34 camps. UNHCR, WFP, IRC, Oxfam, MSF, BRAC, and dozens of other organizations coordinate WASH operations at a scale that rivals a mid-sized city — but with infrastructure that is primarily constructed from temporary materials on terrain that was not engineered for dense habitation. The camps sit in a monsoon-exposed coastal zone subject to annual flooding, cyclone threats, and a dry season that stresses water sources from the opposite direction.

Baseline operational problem. The annual monsoon cycle causes flood-inundation of 20–40% of latrines in Cox’s Bazar in an average year, depending on rainfall intensity and topography. Cyclone threats require rapid WASH system evacuation planning with minimal notice. Cholera and diphtheria outbreaks follow the monsoon and flooding cycle in a pattern that is broadly predictable but poorly anticipated at the operational level — the link between rainfall, latrine flooding, water-point contamination, and outbreak risk is understood qualitatively but not modeled quantitatively enough to drive preemptive action.

WASH service continuity planning in Cox’s Bazar is largely manual and reactive. When a flood event occurs, agencies assess damage after the fact, negotiate desludging and repair priorities across multiple organizations, and respond to outbreak signals that are already days old. The result is a systematic lag between the physical event and the protective operational response — a lag that is measured in outbreak cases rather than in missed alerts.

What τ would change. A τ WASH operational twin for Cox’s Bazar would couple monsoon rainfall forecasts, camp topography, drainage networks, latrine locations, and water-point contamination dynamics into a single physics-faithful predictive system. The operational output would be:

- latrine flood risk and water-point contamination probability by camp sector and block, 72 hours before a monsoon rainfall event, rather than a post-event damage assessment;
- pre-event repair prioritization: which latrines should be raised, reinforced, or temporarily closed before the storm arrives;
- water pre-positioning: where should trucked clean water and chlorination supplies be staged before supply routes are compromised;

- post-event cascade prediction: given flood inundation in Block X, what is the expected contamination spread and outbreak lag time, and where should surveillance and response be concentrated.

This would transform the Cox’s Bazar WASH response from reactive crisis management into anticipatory service protection — a shift that the agencies operating in Cox’s Bazar have explicitly identified as a priority but lacked the tools to achieve.¹⁶¹⁷¹⁸¹⁹²⁰

Why this matters beyond Cox’s Bazar. Cox’s Bazar is the most visible case, but the same operational pattern applies to Kakuma (Kenya), Zaatari (Jordan), Bidi Bidi (Uganda), and the dozens of large camp operations across the Sahel, the Horn of Africa, and South and Southeast Asia. A τ twin validated at Cox’s Bazar would be transferable to any displacement setting with comparable data inputs.

9.2 Case Study 2: Sub-Saharan Africa Health Facility WASH — The Missing Link in Maternal and Child Health Outcomes

Scale and context. Sub-Saharan Africa faces the most acute health facility WASH deficit of any region. The WHO/UNICEF 2020 baseline found that 1 in 4 health facilities in the region lacked basic water service and 2 in 3 lacked adequate sanitation.²¹ This is not evenly distributed: in Kenya, Nigeria, Ethiopia, and the DRC — countries with large rural populations and major primary-care networks — the gaps are largest in precisely the rural district facilities that provide the first and often only point of care for millions of people.

The consequences are measurable. Healthcare-associated infections attributable to WASH failures contribute to an estimated 15% of nosocomial infections in low-income settings and are a documented driver of maternal and newborn mortality, post-surgical complications, and the failure of vaccination programs that depend on sterile technique.²²²³

Climate change is making this worse. Drought is increasingly disrupting piped water supply to rural health facilities in East Africa, and flooding is damaging sanitation infrastructure at facilities that serve catchment populations of tens of thousands. The 2020 baseline data were collected in a period before the climate-WASH intersection had reached its current severity.

Baseline operational problem. Facility WASH improvement programs in Sub-Saharan Africa use static assessment data — primarily WASH-FIT assessments conducted at annual or less frequent intervals — to identify gaps and prioritize investments. These assessments are valuable, but they produce a snapshot that is already outdated by the time it drives a response. They do not predict when a facility will face a water service disruption due to drought, when a flooding event will compromise a facility’s sanitation system, or how the facility’s WASH state will interact with a disease outbreak in its catchment population.

¹⁶UNHCR Bangladesh. “Cox’s Bazar Rohingya refugee emergency.” Operations portal, 2024. <https://www.unhcr.org/countries/bangladesh>

¹⁷OCHA Bangladesh. “Bangladesh Humanitarian Situation Reports.” 2023–2024. <https://reliefweb.int/disaster/tc-2023-000116-bgd>

¹⁸WHO / UNICEF JMP. *WASH in Humanitarian Settings: Progress on Drinking Water, Sanitation and Hygiene in Camps*. Joint Monitoring Programme, 2019.

¹⁹Sphere Association. *The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response*. 4th edition. Geneva: Sphere Association, 2018. <https://spherestandards.org/handbook/>

²⁰IRC. “WASH Programming in Cox’s Bazar.” International Rescue Committee field operations reporting. <https://www.rescue.org/country/bangladesh>

²¹WHO / UNICEF. *WASH in Health Care Facilities: Global Baseline Report 2020*. World Health Organization, 2020. <https://www.who.int/publications/i/item/9789240015951>

²²WHO. “Health care-associated infections fact sheet.” World Health Organization. https://www.who.int/gpsc/country_work/gpsc_ccisc_fact_sheet_en.pdf. See also: Allegranzi B et al. “Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis.” *Lancet* 2011; 377(9761):228–241.

²³World Bank. *The WASH Poverty Diagnostic Initiative*. Washington, DC: World Bank. <https://www.worldbank.org/en/topic/water/publication/the-wash-poverty-diagnostic-initiative>

The result is a reactive system: facilities lose water supply, staff and patients adapt as best they can, infections occur, and the gap is documented in the next assessment cycle — months or years later.

What τ would change. A τ climate-linked WASH continuity twin for a district health network would:

- predict, 30–60 days in advance, which rural health facilities face elevated water shortage probability based on drought forecasts, groundwater level trends, and facility-specific supply characteristics;
- enable pre-positioning of emergency water storage, jerry cans, or tanker delivery before supply fails rather than after;
- alert district health officers to facilities approaching critical WASH thresholds before patient safety is compromised;
- and integrate with disease surveillance systems to identify which facilities face the highest infection amplification risk given their current WASH state and disease burden in the catchment.

Over a five-to-ten year horizon, this predictive capability would allow district health systems to move from reactive WASH crisis management toward a planned, evidence-driven approach to facility WASH resilience — one that can demonstrate which investments reduced service interruptions, reduced infection events, and improved maternal and newborn outcomes with measurable specificity.²⁴²⁵²⁶²⁷²⁸

10 Finance and Investment Pathways

10.1 The scale of existing WASH financing

The WASH sector in health facilities, schools, camps, and vulnerable settlements is already supported by substantial international financing, and the demand for operational intelligence tools is growing as donors require stronger accountability for service outcomes.

Key financing actors and channels include:

- **UNICEF WASH Programme** — over \$800 million per year in global WASH programming, with health facilities and schools as explicit funding priorities. UNICEF is the primary implementing agency for school and camp WASH globally and a key institutional partner for τ deployment.²⁹
- **World Bank WASH Poverty Diagnostic and Investment Program** — the World Bank’s WASH portfolio spans infrastructure investment, institutional strengthening, and analytical tools, with a growing emphasis on service continuity and resilience outcomes.³⁰
- **USAID Water for the World Act Programs** — USAID’s water programs fund WASH in health facilities, schools, and vulnerable communities in priority countries, with accountability frameworks that reward sustained service delivery over one-time infrastructure construction.³¹

²⁴WHO / UNICEF. *WASH in Health Care Facilities: Global Baseline Report 2020*. World Health Organization, 2020. <https://www.who.int/publications/i/item/9789240015951>

²⁵WHO / UNICEF. *Essential services for quality care: Water, sanitation, hygiene, health care waste and electricity services in health care facilities: global progress report*. 2025. https://cdn.who.int/media/docs/default-source/wash-documents/wash-in-hcf/who_unicef_washwasteelectricityinhcfglobalprogressreport2025_web.pdf

²⁶WaterAid. “Health facility WASH research and evidence.” <https://www.wateraid.org/evidence/health-facility-wash>

²⁷USAID. *Water for the World Act: Implementation Plan*. US Agency for International Development. <https://www.usaid.gov/water>

²⁸Cumming O et al. “The implications of three major new trials for the effect of water, sanitation and hygiene on childhood diarrhea and stunting: a consensus statement.” *BMC Medicine* 2019; 17(1):173.

²⁹UNICEF Data. “WASH in schools.” Updated 27 May 2024. <https://data.unicef.org/topic/water-and-sanitation/wash-in-schools/>

³⁰World Bank. *The WASH Poverty Diagnostic Initiative*. Washington, DC: World Bank. <https://www.worldbank.org/en/topic/water/publication/the-wash-poverty-diagnostic-initiative>

³¹USAID. “Water and Sanitation.” <https://www.usaid.gov/global-health/health-areas/water-sanitation-and-hygiene>

- **GAVI (Vaccine Alliance)** — GAVI’s infection control work in health facilities is directly linked to WASH infrastructure. Vaccine-preventable disease programs depend on sterile technique that requires reliable water supply. GAVI has increasing interest in the facility environment conditions that determine whether its investments succeed.³²
- **Humanitarian WASH funding** — OCHA-coordinated humanitarian response plans fund WASH in displacement settings globally. The WASH Cluster at Cox’s Bazar, Kakuma, and other major operations is funded through UNHCR, UNICEF, bilateral donors, and NGO budgets with increasing pressure toward accountability for service continuity outcomes.

10.2 Cost scenarios

Two illustrative cost scenarios bracket the investment range for early-stage τ WASH deployments:

Scenario 1: τ WASH continuity early warning for 500 health facilities in one country — USD 2–6 million

A single-country deployment for a network of 500 district health facilities in a climate-stressed country (Kenya, Nigeria, or Ethiopia as representative cases) would cover: system integration with existing WASH-FIT and HMIS data; a τ physics twin calibrated to the country’s water supply and climate context; facility-level continuity and contamination risk advisory outputs; and operator training and integration with district health management workflows. Expected outcomes: reduction in unplanned facility water outages; reduction in contamination events reaching patients without prior warning; improved time-to-action for district health officers. At WHO’s estimated B:C ratio of 5:1 to 15:1 for WASH interventions in health facilities, a \$4M investment generating even the lower end of this range would represent \$20M in avoided HAI costs, reduced maternal mortality, and improved vaccination program effectiveness.³³

Scenario 2: Regional climate-resilient WASH platform for 5 countries in East Africa — USD 10–25 million

A regional deployment covering Kenya, Ethiopia, Uganda, Tanzania, and Rwanda would extend the health facility layer to include school WASH and urban informal settlement WASH intelligence. This scenario would support 5,000+ health facilities and schools and 200+ camp and informal settlement zones across the region, with a shared climate-data layer, regional τ calibration, and cross-border data exchange for displacement-affected populations. This scale is consistent with existing World Bank and USAID regional WASH programs and would be designed as a public infrastructure layer that NGOs, government health and education ministries, and humanitarian clusters could all access.

10.3 Return on investment framing

WHO’s B:C analysis of WASH interventions in health facilities yields estimates in the range of **5:1 to 15:1**, driven primarily by avoided HAI costs, reduced maternal and newborn mortality, and improved vaccination program effectiveness.³⁴ The World Bank’s WASH Poverty Diagnostic estimates the economic cost of WASH-linked disease burden at **\$260 billion per year** in developing countries.³⁵ Even small percentage improvements in service continuity and contamination prevention

³²GAVI: The Vaccine Alliance. “Health system strengthening.” <https://www.gavi.org/types-support/health-system-strengthening>

³³WHO. “Health care-associated infections fact sheet.” World Health Organization. https://www.who.int/gpsc/country_work/gpsc_ccisc_fact_sheet_en.pdf. See also: Allegranzi B et al. “Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis.” *Lancet* 2011; 377(9761):228–241.

³⁴WHO. “Health care-associated infections fact sheet.” World Health Organization. https://www.who.int/gpsc/country_work/gpsc_ccisc_fact_sheet_en.pdf. See also: Allegranzi B et al. “Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis.” *Lancet* 2011; 377(9761):228–241.

³⁵World Bank. *The WASH Poverty Diagnostic Initiative*. Washington, DC: World Bank. <https://www.worldbank.org/en/topic/water/publication/the-wash-poverty-diagnostic-initiative>

in high-burden settings translate into large health and economic returns relative to the investment cost of an operational twin.

For donors seeking accountability and measurable outcomes, τ WASH tools offer a distinct advantage: because they generate predictions against which actual outcomes can be compared, they create a natural evaluation framework for service continuity performance that static assessment approaches cannot provide.

11 Success Metrics and Benchmark Suite

A credible assessment of τ WASH performance in critical-service settings should be organized around four benchmark families that test whether τ meaningfully outperforms current practice on high-value, difficult operational tasks.

11.1 Benchmark Set A — Health Facility WASH Continuity Under Compound Stress

- Facility service continuity under flood plus outage compound events: does τ predict the timing and severity of water supply interruption more than 24 hours in advance, allowing preemptive action?
- Source contamination early warning: does τ identify elevated contamination risk at facility intakes before quality failures reach patients?
- Minimum-service planning for maternity and neonatal care: can τ identify which care functions are at risk under each plausible stress scenario and recommend specific protective measures?
- Chlorination and storage response: how does τ -guided preemptive chlorination compare to reactive post-event chlorination in terms of time-at-risk?

11.2 Benchmark Set B — School WASH Continuity and Risk Reduction

- School service continuity under heat, flood, and disruption events: does τ reduce the frequency and duration of school water and sanitation failures that trigger closures?
- Handwashing and toilet functionality forecasting: can τ predict when hygiene facilities will become non-functional due to supply or contamination failure, allowing preemptive restocking and repair?
- District-level repair and supply prioritization: across a portfolio of schools with limited maintenance capacity, does τ prioritization improve service continuity outcomes relative to first-come-first-served or fixed-cycle approaches?

11.3 Benchmark Set C — Camp and Displacement WASH Optimization

- Trucking and storage optimization: does τ -guided routing and scheduling reduce cost per safe user-day while maintaining service coverage?
- Desludging and toilet siting under seasonal stress: does τ -informed desludging scheduling reduce overflow and toilet non-functionality during monsoon and peak-demand periods?
- Contamination and outbreak-risk prediction: does τ identify elevated cholera and diarrhea risk in specific camp sectors before outbreak confirmation by surveillance systems?

11.4 Benchmark Set D — Vulnerable Settlement WASH Resilience

- Informal-neighborhood flood contamination mapping: does τ identify which shared water points and low-lying sanitation facilities will be contaminated by a specific rainfall event, with sufficient lead time for protective action?

- Decentralized service continuity: can τ predict when micro-piped or kiosk-based water systems in informal settlements will face supply interruption, and guide pre-positioning of emergency supply?
- Upgrading prioritization: does τ -derived resilience scoring predict future service failure and health outcomes better than existing asset condition surveys, enabling more cost-effective capital allocation?

11.5 A practical scorecard for field operations

Beyond benchmarks, operators should track:

- number of critical-site water-service interruptions per month, before and after τ deployment;
- number of contamination events reaching users before protective action was taken;
- time-to-detection and time-to-response for WASH failure events;
- nonfunctional-toilet incidence at schools, camps, and facilities;
- WASH-linked closures or service suspensions in monitored facilities and schools;
- trucked-water cost per safe user-day in camp operations;
- and capital-upgrade targeting efficiency — health outcomes per dollar invested in WASH improvements when τ risk scoring guides prioritization versus when it does not.

12 Lighthouse Pilots: A First Wave of High-Impact Demonstrations

A well-chosen first wave of five lighthouse pilots would generate the evidence base needed to evaluate τ WASH performance across the full range of critical-service and vulnerable-settlement contexts.

Pilot 1: District health facility network in a flood- and drought-exposed region of East Africa. Goal: reduce WASH-related service continuity failures in care-critical settings and demonstrate 30–60 day advance warning of water supply disruption. Priority countries: Kenya, Ethiopia, or DRC, where the facility WASH gap is severe and climate stress is already affecting rural water supply.

Pilot 2: School-system WASH continuity in a heat- and flood-exposed district. Goal: reduce interruptions, improve hygiene continuity, protect menstrual hygiene management, and reduce school closures attributable to WASH failure. Priority regions: South Asia or West Africa, where heat and monsoon stress both operate on school WASH systems.

Pilot 3: Camp or refugee-settlement WASH operations — Cox’s Bazar or comparable large operation. Goal: improve trucking, storage, sanitation, and outbreak prevention under dynamic monsoon demand. Primary metric: reduction in post-rainfall contamination events and reduction in cholera outbreak lag time.

Pilot 4: Informal-settlement WASH resilience in a flood-prone city. Goal: use τ to prioritize upgrading, drainage improvement, decentralized sanitation, and service continuity in a representative informal urban neighborhood. Priority cities: Dhaka, Lagos, Nairobi, or Maputo, where informal settlement flood exposure and WASH gaps overlap severely.

Pilot 5: Integrated district WASH-health-education emergency dashboard. Goal: prove that one operational twin can serve multiple public services — health facilities, schools, and neighborhood WASH — coherently within a single district control room. This is the integrating pilot that demonstrates the cross-domain coordination value of τ .

13 What Success Would Look Like: A Practical Scorecard

A τ WASH deployment in critical-service and vulnerable-settlement settings would constitute a demonstrated public-good success if, within three to five years of Pilot 1 deployment, the following metrics show measurable improvement attributable to τ -guided decision-making:

- fewer critical-site water-service interruptions during hazard events;
- fewer contamination events reaching users before protective action is taken;
- improved time-to-detection and time-to-response for WASH failures;
- lower nonfunctional-toilet incidence at schools, camps, and health facilities;
- fewer WASH-linked closures or service suspensions;
- lower trucked-water costs per safe user-day in camp operations;
- improved service continuity during floods, heat events, and outages at health facilities;
- and better capital-upgrade targeting per dollar spent on WASH investments.

This scorecard is intentionally anchored in **operational public-good metrics** that are measurable, meaningful to operators, and comparable across settings. It does not depend on resolving metaphysical questions about the τ framework’s ultimate mathematical status — it depends on whether the system helps operators make better decisions faster in the service of vulnerable populations.

14 Governance Guardrails: Ensuring τ Serves Rights and Dignity

Because this cluster of applications directly affects some of the world’s most vulnerable populations — patients in fragile health systems, children in under-resourced schools, refugees and displaced persons in camps, and informal-settlement residents — governance matters as much as technical performance.

14.1 WASH intelligence must support rights, not gatekeeping

The deployment of τ in critical-service settings must be explicitly bounded against misuse. τ must not become a pretext for:

- reducing minimum service levels because algorithmic triage suggests some facilities or zones are “lower priority”;
- excluding informal settlements from WASH investment because their populations are less legible to data systems;
- deprioritizing marginalized communities — including women, girls, and minority ethnic groups — whose WASH needs are systematically under-served;
- or shifting humanitarian obligations onto algorithmic outputs in ways that reduce human accountability for service delivery.

14.2 Human accountability remains primary

Critical decisions affecting WASH service continuity in care-critical and humanitarian settings — facility triage, camp service levels, public health actions, school closure decisions — must remain under accountable human authority. τ provides advisory intelligence; it does not replace the human judgment of facility managers, district health officers, camp coordinators, and school administrators who are ultimately responsible for the populations they serve.

14.3 Privacy and protection safeguards in displacement and informal settings

In camps and informal settlements, data about occupancy, service failure, disease risk, and location-specific vulnerability carry protection risks if they reach actors with interests adverse to the affected populations. Data governance frameworks for τ in these settings must include:

- strict data minimization — collect only what is needed for WASH operational purposes;
- access control — limit data access to humanitarian and service delivery actors with accountability obligations;
- community notification — affected populations should know that τ is in use and what data it uses;
- and audit trails — records of how τ outputs were used in operational decisions, reviewable by oversight bodies.

14.4 Equity as an explicit design objective

The point of τ WASH in these settings is not to optimize average service performance while leaving the hardest settings behind. The point is to improve WASH resilience in exactly the places where ordinary infrastructure planning fails most often — the rural district clinic, the camp block most exposed to flooding, the informal neighborhood with no piped supply, the school with the highest diarrhea absenteeism. Equity must be a design constraint, not an afterthought.

15 Connections to the Broader τ Portfolio

This paper occupies a distinctive position in the τ impact portfolio because it demonstrates that τ 's capabilities are not only relevant to infrastructure and forecasting — they are directly relevant to care, dignity, and protection.

The connections across the portfolio are substantive:

- **Weather and disaster resilience cluster:** hazard anticipation and infrastructure continuity under compound stress — flood, cyclone, drought, heat — are the same capabilities that drive WASH continuity in health facilities, schools, and camps;
- **Climate adaptation cluster:** long-range resilience planning and climate-exposed community protection are the same objectives as climate-resilient WASH upgrading in informal settlements;
- **Agriculture and water cluster:** water availability, quality, and allocation dynamics in basins and aquifers directly determine the source-water reliability on which health facilities, schools, and settlements depend;
- **Energy cluster:** outage-sensitive essential services — including WASH pumping, treatment, and storage — require the same power-WASH coupling that the τ energy portfolio addresses;
- and **One Health and biology cluster:** infection prevention, disease surveillance, and WASH-health coupling are among the clearest examples of τ 's potential to integrate physical and biological system intelligence in service of public health.

Paper 5 is not a side paper in the water portfolio. It is one of the clearest demonstrations of what the τ framework is ultimately about: **physical fidelity in service of human outcomes.**

16 Bottom Line: A First-Tier Public-Good Opportunity

Under the planning assumptions of this yellow paper, WASH in health facilities, schools, camps, and climate-vulnerable settlements is a **first-tier τ public-good opportunity** for three simple reasons.

First, **the burden is large and well-documented.** 1.1 billion people are served by health facilities lacking basic water; 447 million children lack basic drinking water at school; 100 million people are forcibly displaced; 1.1 billion people live in climate-exposed informal settlements. These numbers are not projections — they are the current official baseline from WHO, UNICEF, UNHCR, and UN-Habitat.

Second, **the official need is already fully acknowledged.** The institutions responsible for these populations — WHO, UNICEF, UNHCR, World Bank, USAID, and dozens of major NGOs — have explicitly identified service continuity, climate resilience, and operational prediction as capabilities they need and currently lack. τ does not need to convince these institutions that the problem matters. It needs to demonstrate that it can help solve it.

Third, **the value of better continuity, contamination, and coordination intelligence is immediate and humane.** Unlike forecasting or infrastructure optimization in well-resourced settings, WASH failures in health facilities, schools, and camps cause direct, measurable harm — infections, deaths, school absences, outbreak deaths, degraded maternal and newborn outcomes — that occur within hours to days of the service failure. The gap between current practice and τ 's potential is a gap measured in human welfare outcomes, not only in efficiency metrics.

This is where τ would show whether a high-fidelity operational water twin can do something profoundly practical:

Help keep care safe, schools open, camps dignified, and vulnerable settlements healthier under growing climate and service stress.

That is a very strong reason to include this paper as the final component of the τ Water/WASH portfolio — and to make it a first-wave deployment priority.

SDG Alignment: SDG 3 (Good Health and Well-Being) · SDG 4 (Quality Education) · SDG 6 (Clean Water and Sanitation) · SDG 10 (Reduced Inequalities) · SDG 13 (Climate Action)

17 References

Source: Full manuscript text integrated from Public-Good Briefing draft.

18 Dossier accountability addendum

The following addendum records the release-facing accountability layer for this dossier: claim boundaries, baseline evidence, upstream dependencies, translation assumptions, scenario bands, scorecard rationales, benchmark requirements, governance guardrails, and related Panta Rhei surfaces. It is intentionally downstream of the full source argument above.

Impact thesis

A Public-Good Briefing on how τ could improve WASH service continuity in health facilities, schools, refugee camps, and climate-vulnerable settlements. The v3 impact thesis is conditional: a Tau-grade WASH service continuity twin for health facilities, schools, camps, and climate-vulnerable settlements would become valuable if it improves benchmarked public decisions while preserving transparent uncertainty, reviewability, and governance control.

18.1 Public-good burden and baseline evidence

A Public-Good Briefing on how τ could improve WASH service continuity in health facilities, schools, refugee camps, and climate-vulnerable settlements. The public-good burden is treated here as an institutional decision problem: existing agencies already monitor parts of the domain, but the operational handoff from data to timely, auditable action remains incomplete.

18.1.1 External evidence baseline

- **WHO.** "1 in 4 people globally still lack access to safe drinking water – WHO, UNICEF." 26 August 2025 [8]: source-page evidence item.
- **WHO.** "Sanitation" fact sheet. 22 March 2024, WHO. "Sanitation" fact sheet. 22 March 2024 [11]: source-page evidence item.
- **WHO Global Health Observatory.** "Water, sanitation and hygiene: burden of disease." [9]: source-page evidence item.
- **WHO / UNICEF.** "Countries making unprecedented efforts, but billions still lack basic services in health care facilities – WHO/UNICEF new report warns." 24 September 2025 [5]: source-page evidence item.
- **WHO / UNICEF.** **WASH in Health Care Facilities: Global Baseline Report 2020.** World Health Organization, 2020 [7]: source-page evidence item.
- **WHO.** "Health care-associated infections fact sheet." World Health Organization. See also: Allegranzi B et al. "Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis." *Lancet* 2011; 377(9761):228–241, WHO. "Health care-associated infections fact sheet." World Health Organization. See also: Allegranzi B et al. "Burden of endemic health-care-associated infection in developing coun [10]: source-page evidence item.
- **World Bank.** **The WASH Poverty Diagnostic Initiative.** Washington, DC: World Bank [12]: source-page evidence item.
- **WHO / UNICEF.** **Essential services for quality care: Water, sanitation, hygiene, health care waste and electricity services in health care facilities: global progress report.** 2025 [6]: source-page evidence item.
- **UNICEF Data.** "WASH in schools." Updated 27 May 2024, UNICEF Data. "WASH in schools." Updated 27 May 2024 [4]: source-page evidence item.

- **UNHCR. Global Report 2024. 17 June 2025**, UNHCR. Global Report 2024. 17 June 2025 [3]: source-page evidence item.

18.2 Current institutional landscape

The relevant landscape includes public agencies, research infrastructures, standards bodies, development-finance channels, and domain review communities represented in the evidence base, including WHO / UNICEF. "Countries making unprecedented efforts, WHO / UNICEF. WASH in Health Care Facilities: Global Baseline Report 2020. World Health Organization, WHO Global Health Observatory. "Water, WHO. "1 in 4 people globally still lack access to safe drinking water – WHO, WHO. "Health care-associated infections fact sheet." World Health Organization. See also: Allegranzi B et al. "Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis." Lancet 2011; 377(9761):228–241, WHO. "Sanitation" fact sheet. 22 March 2024. These references are evidence and adoption surfaces, not endorsements or deployment partners.

18.3 Capability gap

The practical gap is a benchmarkable translation gap: current systems expose useful data or partial models, but they do not yet provide a single law-faithful, bounded-error decision layer for WASH service continuity twin for health facilities, schools, camps, and climate-vulnerable settlements.

18.4 Tau framework dependency map

Surface	Role in this dossier
Build the Tau-Kernel	finite address and scalar foundation
Recover Core Mathematics	mathematical bridge and model interface
Derive Physics	physical readout and domain translation candidate
Results lane	upstream consequences to be mapped precisely during release preparation
direct-registry-mapping-withheld	no direct Registry object is asserted until a substantive Corpus mapping is available
public-docs-mapping-withheld	TauLib module links are asserted only where public documentation exposes a clear surface
Release Manifest	release baseline
Predictions and Falsification	empirical accountability route

18.5 Translation assumptions and missing engineering

Required domain model: **WASH service continuity twin for health facilities, schools, camps, and climate-vulnerable settlements.**

First benchmarkable test: service interruption, quality, access, and emergency-response outputs against WASH facility and humanitarian service data.

- domain-specific model construction
- data ingestion and validation
- benchmark harness
- pilot protocol

- independent review workflow


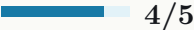

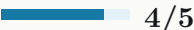


18.6 Impact mechanism chain

Public-good burden → external evidence baseline → τ capability hypothesis → upstream Results / Corpus / Verify dependency → translation assumptions → benchmarked pilot → governed adoption pathway.

18.7 Scenario bands

Band	Scenario summary	Confidence
Conservative	A narrow shadow-mode pilot improves one bounded decision task for WASH in Health Facilities, Schools, Camps, and Climate-Vulnerable Settlements without operational authority.	medium
Realistic	A reviewed prototype strengthens several public-sector workflows for WASH in Health Facilities, Schools, Camps, and Climate-Vulnerable Settlements after benchmark comparison with incumbent systems.	medium-low
Optimistic	A reusable public-good intelligence layer becomes plausible for WASH in Health Facilities, Schools, Camps, and Climate-Vulnerable Settlements after external validation and transparent governance review.	low

18.8 Impact scorecard

Public-good scale	 5/5	The affected public-good burden is large or institutionally significant within the portfolio.
Tau fit	 4/5	The proposed pathway depends on coupled state, bounded uncertainty, and compositional modelling rather than isolated prediction alone.
Evidence proximity	 5/5	The evidence base is anchored in public institutions, official monitoring systems, or established scientific reviews.
Measurability	 4/5	A first benchmark can be framed against incumbent public datasets, institutional records, or operational decision metrics.
Adoption readiness	 3/5	Adoption remains conditional on domain review, governance fit, data access, and institutional integration.
Equity leverage	 5/5	The pathway can prioritize underserved or vulnerable populations where public access and safeguards are built in.

18.9 Candidate pilot pathways

WASH continuity pilot with health, education, humanitarian, and water-service agencies

18.10 Benchmark suite and success metrics

Type	Incumbent line	base-	Required benchmark	Tau	Success metric	Validator
translation benchmark	current public or institutional systems in the domain		service interruption, quality, access, and emergency-response outputs against WASH facility and humanitarian service data		pre-registered accuracy, latency, uncertainty, or decision-quality metric	independent domain reviewers
governance benchmark	existing audit, disclosure, and reporting practice		transparent assumption, data, model, and failure-mode disclosure		reviewable evidence pack and adverse-outcome protocol	public-sector or expert governance panel
equity benchmark	current service-quality, or exposure disparities	access, or	documented way for underserved or vulnerable without exclusion	path-underserved users hidden	distributional benefit and risk review before pilot expansion	equity, community, or public-interest review process

18.11 Governance and risk guardrails

- Human oversight for any operational use.
- Public benchmark disclosure before institutional adoption.
- Equity access review for underserved or vulnerable communities.
- Data-rights and privacy controls for operational datasets.
- Misuse-prevention and adverse-outcome monitoring.
- Adverse-outcome monitoring with a documented escalation path.
- External domain review before pilot expansion.

18.12 Related Results / Corpus / Verify / Publications

This dossier is downstream of Results, Corpus, Verify, and Publications surfaces. It is not a Registry object. Direct Registry or TauLib links are asserted only where the mapping is substantive rather than decorative.

18.13 Bibliography and external evidence

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Panta Rhei Research Program

Public-Good Impact Dossier

τ for WASH in Health Facilities, Schools, Camps, and Climate-Vulnerable Settlements

Dossier ID: PGID-WASH-04 Portfolio: Water / WASH Release: May 2026
publication-ready release

Conditional scenario map. Domain review pending. Deployment, product, validation, certified-impact, and policy-commitment claims are not made.

Public contact and review routes

Website: panta-rhei.site

Contact: panta-rhei.site/engage/contact/

Public discussion: github.com/orgs/Panta-Rhei-Research/discussions

General: hello@panta-rhei.site

Corrections: errata@panta-rhei.site

Media: press@panta-rhei.site