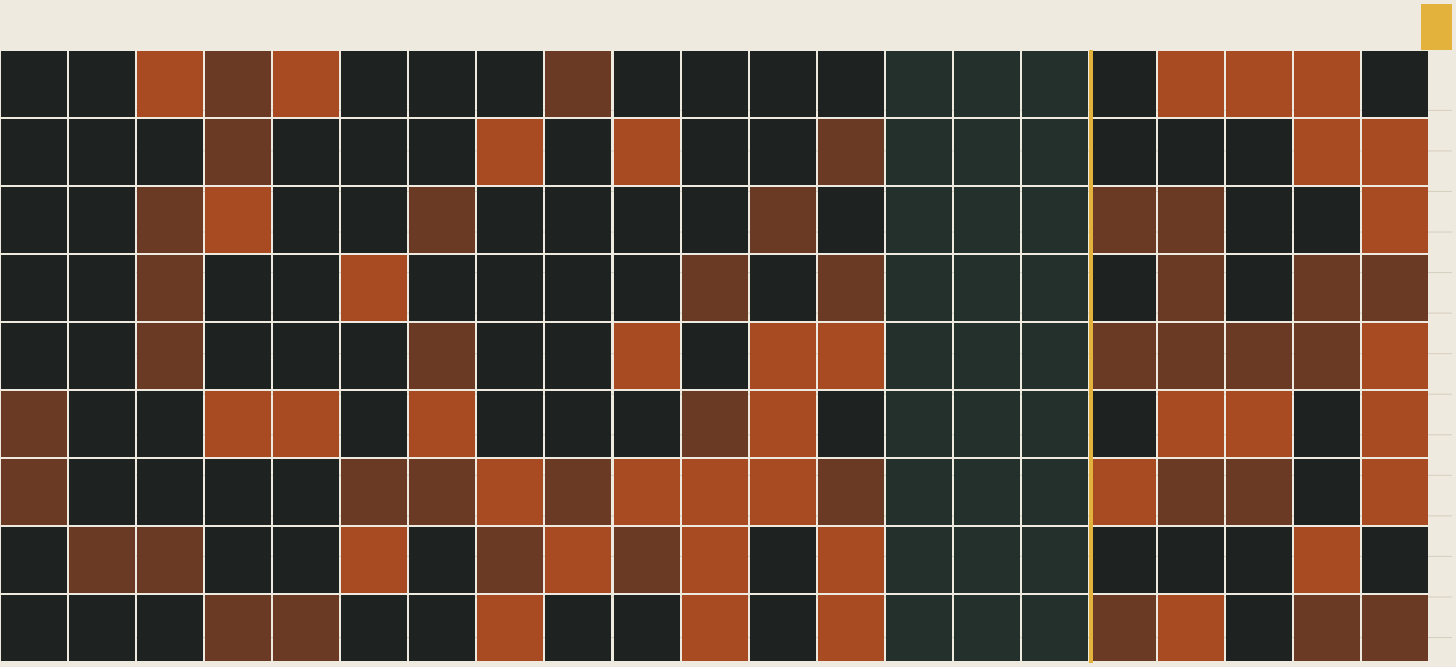

A SAHILTAYAL.COM PRODUCTION · FIELD GUIDE · VOLUME ONE · 2026

UPKEEP

The work that keeps the world from falling apart

Everything you rely on is falling apart, slowly, and someone is quietly stopping it. Civilisation is less a pile of inventions than a daily argument with decay — and the people who win that argument are rewarded with nothing happening.

This field guide accompanies the interactive production at sahiltayal.com/upkeep/. It contains the full text, a paper version of the simulation, the reflection audit, the reading ladder and the limits of the argument. Claims are labelled: ESTABLISHED (documented, traceable), INTERPRETATION (a reading others may dispute), HYPOTHESIS (plausible, untested here) and METAPHOR (a way of seeing, not evidence).

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01 · DEFINITION & BOUNDARIES

What maintenance is — and is not

Maintenance is recurring work that keeps an existing thing performing its function despite wear, drift and changing conditions. Three words carry the weight: *recurring* (it is never finished), *existing* (it begins after the ribbon is cut) and *function* (it is judged by what a thing does, not by how it looks).

It sits in a family of neighbouring ideas, and most confusion comes from blurring them:

- **Repair** restores function after a failure. It is maintenance's emergency sibling: louder, costlier, easier to see.
- **Preservation** keeps form even when function has gone — a museum keeps a steam engine; a railway maintains one.
- **Renovation and upgrade** change what a thing does. They borrow maintenance's tools but answer a different question.
- **Care** is wider: an ethical relationship that includes people, animals and places. Maintenance is often care performed on objects and systems.
- **Innovation** brings a new thing into the world. Every innovation is also a promise that someone will maintain it.

Engineers distinguish four modes. **Preventive** maintenance acts on a schedule. **Corrective** maintenance acts after a fault. **Predictive** (or condition-based) maintenance acts on measured signs of deterioration. **Deferred** maintenance is maintenance that was due and was not done — a liability that rarely appears on any balance sheet.

[INTERPRETATION] Two boundaries matter for everything that follows. First, *maintained is not the same as unchanged*: a road that has been resurfaced eleven times is the same road only in the sense that matters to the people driving on it. Second, maintenance includes *judgement about what not to maintain*. Letting something go on purpose is part of the craft, not a failure of it.

02 · HISTORICAL & CULTURAL ORIGINS

An old argument with decay

[ESTABLISHED] In 97 CE the Roman senator Sextus Julius Frontinus was appointed *curator aquarum*, the official responsible for Rome's aqueducts. His treatise *De aquaeductu* is, among other things, a maintenance report: it catalogues leaks, neglected channels and illegal taps that diverted public water.

[ESTABLISHED] Plutarch recorded the puzzle now called the Ship of Theseus: the Athenians kept Theseus's ship by replacing its rotten timbers, and philosophers argued about whether it remained the same ship. The question has outlived the ship because it is really a question about what maintenance preserves.

[ESTABLISHED] In the Netherlands, regional water boards (*waterschappen*) that manage dikes, polders and water levels are among the country's oldest governing institutions; some trace their origins to the thirteenth century. A low country cannot defer the upkeep of its dikes, and it built institutions to match.

[ESTABLISHED] In 1969 the artist Mierle Laderman Ukeles wrote her *Manifesto for Maintenance Art*, contrasting the prestige of "development" with the unrecognised labour of "maintenance" — including the domestic labour she was doing as a new mother. From 1977 she became the (unsalaried) artist-in-residence of the New York City Department of Sanitation; in *Touch Sanitation* (1979–80) she set out to shake hands with every sanitation worker in the city and thank them.

[ESTABLISHED] In 1978 F. Stanley Nowlan and Howard Heap, of United Airlines, published *Reliability-Centered Maintenance* for the US Department of Defense. Analysing aircraft component data, they argued that many failures are not driven by age, so blanket fixed-interval overhauls often do not improve reliability — and can introduce new faults. It reshaped how aviation, and later many industries, decide what to maintain and when.

[INTERPRETATION] Across these origins, one pattern repeats: societies that cannot afford failure (desert cities, low countries, airlines) build explicit institutions for upkeep. Societies that can defer failure tend to defer the institutions too.

03 · MAJOR THEORIES & COMPETING INTERPRETATIONS

Six ways to think about upkeep

[METAPHOR] **1. The entropy frame.** Physicists' second law of thermodynamics is often borrowed to say that disorder is the default and order costs energy. As physics, the law applies to closed systems; bridges, codebases and friendships are open systems. As metaphor it is powerful and roughly right: left alone, ordered things drift towards states nobody chose.

[INTERPRETATION] **2. Use-centred history.** The historian David Edgerton (*The Shock of the Old*, 2006) argues that histories organised around inventions miss most of technology's actual life: the long decades of use, adaptation and repair — and the old technologies that persist alongside the new.

[INTERPRETATION] **3. The innovation critique.** Andrew Russell and Lee Vinsel ("Hail the maintainers", 2016; *The Innovation Delusion*, 2020) argue that a culture fixated on innovation systematically undervalues the work that keeps things running, with consequences for infrastructure, careers and public budgets. They co-founded The Maintainers, a research network on these questions.

[INTERPRETATION] **4. Broken-world thinking.** Steven J. Jackson ("Rethinking Repair", 2014) proposes starting analysis from erosion and breakdown rather than from novelty. On this view, repair is not a footnote to design but a site where knowledge, skill and even invention happen.

[INTERPRETATION] **5. Care ethics.** Berenice Fisher and Joan Tronto defined caring broadly as the activity through which we maintain, continue and repair our "world" so that we can

live in it as well as possible (Tronto, *Moral Boundaries*, 1993). This places maintenance inside ethics — and asks who is assigned to do it.

[INTERPRETATION] **6. Labour and work.** Hannah Arendt (*The Human Condition*, 1958) distinguished *labour*, cyclical activity that sustains life and leaves no lasting trace, from *work*, which fabricates durable things. Maintenance sits awkwardly between them: it is labour performed so that work can last.

Where they disagree. Is maintenance *conservative* — preserving whatever exists, including arrangements that ought to change — or *radical*, a refusal of throwaway culture? Is chronic under-maintenance a moral failure, or a rational response to budgets and discounting the future? Does valuing maintenance mean valuing maintainers, or merely praising them while paying them the same? None of these is settled, and this page does not settle them.

04 · SCIENTIFIC & SCHOLARLY EVIDENCE

What the evidence actually says

[ESTABLISHED] **Life is maintenance.** Tomas Lindahl's work (including a 1993 *Nature* review) showed that DNA is chemically unstable and accumulates damage continuously under normal cellular conditions; without repair systems, genomes would not persist. The 2015 Nobel Prize in Chemistry went to Lindahl, Paul Modrich and Aziz Sancar for mechanistic studies of DNA repair. The 2016 Nobel Prize in Physiology or Medicine went to Yoshinori Ohsumi for discoveries about autophagy, the process by which cells break down and recycle their own components.

[ESTABLISHED] **Software decays without work.** Meir Lehman, studying large systems including IBM's OS/360, formulated "laws of software evolution" (summarised in a 1980 *Proceedings of the IEEE* paper). Two are central here: a program used in the real world must be continually adapted or it becomes progressively less useful; and its complexity increases unless work is done to reduce it.

[ESTABLISHED] **Not every failure is about age.** Nowlan and Heap's reliability-centered maintenance analysis (1978) found that many component failure patterns did not show a clear wear-out age. The practical consequence: good maintenance is targeted by consequence and failure mode, not applied uniformly, and run-to-failure is a legitimate choice for some cheap, non-critical items.

[ESTABLISHED] **Timing changes cost.** Road agencies, including the US Federal Highway Administration, promote *pavement preservation*: applying lower-cost treatments while pavement is still in good condition rather than waiting until it needs reconstruction. The underlying logic — that deterioration accelerates and repair costs rise steeply once a threshold is crossed — is the logic the Lab below makes visible.

[ESTABLISHED] **Upkeep of places can affect lives.** A citywide cluster-randomised trial in Philadelphia (Branas et al., *PNAS*, 2018) found that remediating blighted vacant lots — clearing rubbish, planting grass and trees, regular upkeep — was followed by significant reductions in gun violence in neighbourhoods below the poverty line, compared with control lots.

[INTERPRETATION] **Treat famous percentages with care.** It is widely repeated that maintenance consumes the majority of a software system's lifetime cost. Estimates vary widely, depend on what counts as "maintenance", and many trace back to studies from the 1970s and 1980s. The direction of the claim is plausible; precise figures are not well established, so none are quoted here.

[INTERPRETATION] **The preparedness paradox.** When maintenance succeeds, the evidence of success is an absence. Y2K remediation is the classic case: large investments were followed by few serious failures, and people still argue about whether the effort was necessary. The disagreement persists because the counterfactual cannot be observed directly.

The Long Road

[METAPHOR] The online Lab simulates forty years of a small town. On paper, run a shorter version with a pencil and a die. The numbers are invented to make a shape visible; they describe no real asset.

Set-up. Draw four boxes: Bridge 80, Pipes 70, Roof 60, Server 75 (condition out of 100). Each year you have 12 units. Choose how many go to upkeep; the rest go into a building fund.

- **Decay.** Each asset loses 1 point, plus 5 × (damage)², where damage = (100 − condition)/100, plus half a die roll. Worse things decay faster.
- **Upkeep.** A point of condition costs 0.25 units on a good asset (70+), 0.6 on a fair one (40–69) and 1.5 on a poor one (below 40). Cap at 95.
- **Failure.** At 10 or below, the asset fails. Emergency repair costs 30 units, paid before anything else, and restores it only to 55.
- **Building.** Every 22 units in the fund buys a new asset at 100. Add a box: it decays from next year.
- **The shadow.** Copy your sheet and run it again with zero upkeep and the same dice. The difference in failures is the work nobody sees.

What to watch for. In the online model, a common pattern is that towns which neglect upkeep end up building *fewer* new things, because emergencies are paid first; and there is often a narrow band of budget share where outcomes flip from a failure spiral to stability. Check whether your paper run behaves the same way, and ask what real systems would break the pattern.

Year	Bridge	Pipes	Roof	Server	New	Upkeep	Fund	Failures
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

05 · REAL-WORLD EXAMPLE &MIDDOT; GENOA, 2018

Example one: a bridge that hid its decay

[ESTABLISHED] The Polcevera viaduct in Genoa, widely known as the Morandi Bridge after its engineer Riccardo Morandi, opened in 1967 and carried a major motorway route through the city. On 14 August 2018, during a storm, a section of it collapsed. Forty-three people were killed.

[ESTABLISHED] The bridge's distinctive design suspended the deck from stays in which steel tendons were encased in concrete. That made the most critical steel hard to inspect directly; its condition had to be inferred. Morandi himself had published concerns about the deterioration of concrete from the sea air and industrial pollution, and concerns about the structure's condition were raised in the years before the collapse.

[ESTABLISHED] The motorway was operated under a concession by Autostrade per l'Italia. Investigations and criminal proceedings followed, involving dozens of defendants. A replacement, the Genova San Giorgio bridge designed by Renzo Piano, opened in 2020.

[INTERPRETATION] Three maintenance lessons sit inside this tragedy, independent of how courts assign responsibility. **Inspectability is a design property**: a structure that hides its decay converts maintenance into guesswork. **Deterioration is quiet until it is not**: decades of gradual change ended in seconds. **Incentives shape upkeep**: when the party responsible for maintenance is also the party paying for it and reporting on it, the system depends heavily on independent oversight.

[HYPOTHESIS] A plausible but contested reading is that public infrastructure of the post-war building boom reached, around the same decades, the age at which its maintenance needs climbed — while public attention remained on new projects. This page treats that as a hypothesis worth testing country by country, not a demonstrated pattern.

06 · REAL-WORLD EXAMPLE &MIDDOT; OPEN-SOURCE SOFTWARE, 2024

Example two: the backdoor that came through the help

[ESTABLISHED] xz Utils is a small open-source compression tool and library included in many Linux distributions. For years it was maintained largely by one volunteer, Lasse Collin.

[ESTABLISHED] Starting around 2021, a contributor using the name "Jia Tan" began submitting helpful patches. Other accounts publicly pressed the maintainer to accept more help and move faster. Over roughly two years, Jia Tan gained trust and maintainer-level access.

[ESTABLISHED] On 29 March 2024, Andres Freund, a software engineer, posted to the oss-security mailing list that upstream xz releases contained a backdoor that could compromise SSH servers. He had noticed SSH logins on a test system using unusual

amounts of CPU and producing errors in a debugging tool. The vulnerability was catalogued as CVE-2024-3094. It was found before it reached most stable distribution releases.

[ESTABLISHED] It was not the first warning. In 2014, the Heartbleed vulnerability in OpenSSL — software that secured much of the web's encrypted traffic — drew attention to how few people, with how little funding, were maintaining it. Nadia Eghbal's report *Roads and Bridges* (2016) described open-source code as public infrastructure resting on largely unseen and often unpaid labour.

[INTERPRETATION] What makes the xz case distinctive is that the attack *exploited the maintenance shortage itself*. The vulnerability was not just a bug in code; it was a tired maintainer, a request for help, and a helper who was not what he seemed. The fix for under-maintenance (more hands) became the attack vector. And the discovery depended on one person paying close attention to something being half a second slow.

07 · SERIOUS COUNTEREXAMPLE &MIDDOT; ISE, JAPAN

The counterexample: a shrine rebuilt every twenty years

[ESTABLISHED] At Ise Jingu, Shinto's most important shrine complex, the principal sanctuaries are ritually rebuilt on an adjacent site roughly every twenty years in a ceremony called *Shikinen Sengu*. Tradition dates the practice to the late seventh century; the 62nd rebuilding took place in 2013. The old structures are dismantled, and many of their materials are passed on to other shrines.

[INTERPRETATION] Ise challenges this page's thesis in a useful way. It does not extend the life of its buildings through upkeep; it *renews* them completely, on schedule, before decay becomes failure. What is preserved is not timber but knowledge: carpentry skills, rituals and forms transmitted from one generation of craftspeople to the next. The continuity is in the people.

[INTERPRETATION] Three corrections follow. First, maintenance is not always the opposite of replacement; sometimes planned renewal is the maintenance strategy. Second, the thing being maintained may not be the object at all, but the capacity to make it. Third, some things should not be kept running indefinitely — systems whose function has become harmful, or whose upkeep consumes what a replacement would save. The upkeep instinct, unexamined, can become an argument for preserving anything that merely exists.

08 · MISCONCEPTIONS

Six oversimplifications

- **"Maintenance is the opposite of innovation."** A great deal of invention happens in maintenance — workarounds, adaptations and improved procedures that rarely get patents or press releases.

- **“Nothing broke, so it wasn’t necessary.”** Absence of failure is weak evidence either way. It may mean the maintenance worked, or that it was excessive. Only the record of conditions and near-misses can tell you which.
- **“New things need less maintenance.”** Often true for a while. But every new thing is added to the stock that must be maintained, and complex new systems can carry heavier, less familiar upkeep.
- **“Maintenance is unskilled.”** Diagnosis — deciding what a symptom means and what to do first — is among the most demanding forms of expertise, and much of it is tacit.
- **“Fix it when it breaks is always cheaper” (or always more expensive).** Both are overgeneralisations. Reliability-centered maintenance explicitly allows run-to-failure where failures are cheap and safe. The error is applying either rule everywhere.
- **“Broken windows proves that upkeep prevents crime.”** The 1982 “broken windows” essay by James Q. Wilson and George Kelling became associated with aggressive order-maintenance policing, whose effects and harms are strongly contested. Evidence about *physically maintaining places* (such as the Philadelphia vacant-lot trial) is a different question and should not be used to vindicate a policing strategy.

09 · ETHICAL IMPLICATIONS & UNINTENDED CONSEQUENCES

Who pays for nothing happening?

[INTERPRETATION] **Deferred maintenance is borrowing without a ledger.** When a public body skips upkeep, it moves costs onto future users, often at a higher price, and the transfer appears in no budget line. Few other intergenerational transfers are so large and so unrecorded.

[INTERPRETATION] **Visibility shapes reward.** Opening something new produces a photograph; preventing a failure produces nothing to photograph. This plausibly biases politicians, managers and individuals towards the new, and it leaves maintainers making a structurally weak case for their own budgets.

[ESTABLISHED] **The work has a social distribution.** Domestic, cleaning, sanitation and care labour — much of the world’s maintenance — is disproportionately done by women and by lower-paid and marginalised workers. Ukeles’s manifesto and care ethics both began from this observation.

[INTERPRETATION] **Unintended consequences run both ways.** Over-maintenance wastes resources and, as Nowlan and Heap noted, intrusive work can itself introduce faults. Predictive maintenance built on sensors can drift into surveillance of the people doing the work. Maintaining an unjust institution well can make it more durable.

[ESTABLISHED] **Who is allowed to maintain?** Manufacturers can make repair difficult through design, parts restrictions and software locks. The right-to-repair movement contests this; in 2024 the European Union adopted a directive promoting the repair of goods.

[INTERPRETATION] **Free labour is not free.** The xz case shows a security cost of relying on unpaid maintainers. Respecting maintenance means funding it, staffing it and giving it authority — not only thanking it.

10 · CONNECTIONS

Upkeep across disciplines

- **Biology.** Walter Cannon's *homeostasis* (*The Wisdom of the Body*, 1932) describes organisms actively maintaining stable internal conditions. DNA repair and autophagy are maintenance at molecular scale.
- **Ecology.** Many landscapes people consider "natural" are maintained by recurring disturbance, including fire management practised by Indigenous communities for generations.
- **Economics.** National accounts record *depreciation* of capital, and much infrastructure spending is spent simply keeping existing capital in service. Whether that spending is counted as investment or cost shapes how it is defended.
- **Software.** Ward Cunningham's 1992 metaphor of *technical debt* names the future work created by present shortcuts — deferred maintenance with interest.
- **Language.** Languages persist through use; when communities stop speaking them, they can be lost within a few generations. Revitalisation is maintenance of a living system.
- **Politics.** Steven Levitsky and Daniel Ziblatt (*How Democracies Die*, 2018) argue that democracies depend on unwritten norms, such as mutual toleration and forbearance, that must be continually practised to survive.
- **Art conservation.** Conservators debate how far to intervene: whether to restore an original appearance or stabilise a work as it has aged — the Ship of Theseus with a budget.
- **Everyday life.** Relationships, health and skills are often described as "needing maintenance". This is a *metaphor*: illuminating, but not a research finding, and it can mislead if it suggests people are machines.

11 · LIMITS OF THE ARGUMENT

What This Does NOT Show

- It does not show that more maintenance is always better. Over-maintenance is real, and choosing what to let go is part of the work.
- It does not show that new things are bad or that innovation is overrated in every case. The claim is about balance and visibility, not a reversal of values.

- The Lab’s numbers are illustrative. Its decay curves and repair costs are invented to make a shape visible; they are not calibrated to bridges, pipes, software or any real asset class.
- The Genoa and xz examples do not have single causes. This page offers maintenance-focused interpretations; it does not assign legal or personal blame.
- It does not show that Y2K remediation, or any particular preventive programme, was necessary or sufficient. Counterfactuals remain contested.
- It does not show that maintainers are morally superior to inventors, or that every under-maintained system reflects negligence rather than real trade-offs.
- Personal-life analogies (“relationships need maintenance”) are metaphors, not evidence.

12 · REFLECTION EXERCISE

The Upkeep Audit

This is an audit, not a test. Nothing is scored, nothing is uploaded, and there are no right answers. Your notes stay in this browser unless you download them.

1. Name five things you rely on every week that you did not make.

e.g. the water supply, a bus route, a library, an app, a friend who always picks up

2. For each, who keeps it working? Write “I don’t know” where that is true.

Not knowing is information, not a failure.

3. What do you maintain that nobody would notice unless you stopped?

Household, work, family, a community, your own body or skills.

4. What maintenance are you deferring right now, and what is the delay costing?

Cost can be money, time, trust, risk or attention.

5. What are you maintaining out of habit that might deserve to be retired?

Letting go deliberately is also part of upkeep.

6. Whose invisible upkeep do you benefit from that you have never acknowledged?

You decide whether to do anything about it.

13 · ANNOTATED READING LADDER

Climb as far as you like

Every item exists and can be found. URLs point to publishers, journals or primary records; books without a stable free copy are listed without links. Check editions and availability yourself.

RUNG 1 &MIDDOT; AN EVENING

Andrew Russell & Lee Vinsel, “Hail the maintainers”, *Aeon*, 7 April 2016.

The essay that popularised the maintenance turn. Start here for the argument against innovation-worship.

https://aeon.co/essays/innovation-is-overvalued-maintenance-often-matters-more

Nadia Eghbal, *Roads and Bridges: The Unseen Labor Behind Our Digital Infrastructure*, Ford Foundation, 2016.

Free report on open-source software as public infrastructure. Essential context for the xz case.

https://www.fordfoundation.org/work/learning/research-reports/roads-and-bridges-the-unseen-labor-behind-our-digital-infrastructure/

Mierle Laderman Ukeles, *Manifesto for Maintenance Art 1969!*

Short, sharp and widely reproduced in exhibition catalogues and art-history anthologies. Read it alongside her *Touch Sanitation* project.

RUNG 2 &MIDDOT; A WEEKEND

Stewart Brand, *How Buildings Learn: What Happens After They’re Built*, Viking, 1994.

Buildings as things that change in use. Generous, illustrated, practical.

David Edgerton, *The Shock of the Old: Technology and Global History since 1900*, Profile, 2006.

A use-centred history that dethrones invention as the main event.

Lee Vinsel & Andrew L. Russell, *The Innovation Delusion*, Currency, 2020.

The book-length argument, with case studies from infrastructure to software.

Andres Freund, “backdoor in upstream xz/liblzma leading to ssh server compromise”, oss-security mailing list, 29 March 2024.

The primary disclosure. Technical, but the opening paragraphs are readable by anyone.

https://www.openwall.com/lists/oss-security/2024/03/29/4

RUNG 3 &MIDDOT; A SEMINAR

Steven J. Jackson, “Rethinking Repair”, in Gillespie, Boczkowski & Foot (eds), *Media Technologies*, MIT Press, 2014.

The foundational statement of “broken-world thinking”.

Stephen Graham & Nigel Thrift, “Out of Order: Understanding Repair and Maintenance”, *Theory, Culture & Society* 24(3), 2007.

Urban geography of breakdown and repair; why cities are always partly broken.

https://journals.sagepub.com/doi/10.1177/0263276407075954

Joan C. Tronto, *Moral Boundaries: A Political Argument for an Ethic of Care*, Routledge, 1993.

Care ethics and the politics of who does the maintaining.

Hannah Arendt, *The Human Condition*, University of Chicago Press, 1958.

Labour, work and action: the philosophical frame for why upkeep is undervalued.

RUNG 4 &MIDDOT; THE TECHNICAL SHELF

F. Stanley Nowlan & Howard F. Heap, *Reliability-Centered Maintenance*, report for the US Department of Defense, 1978 (DTIC AD-A066579).

Why fixed overhaul schedules often fail, and how to choose maintenance by consequence.

https://apps.dtic.mil/sti/pdfs/ADA066579.pdf

M. M. Lehman, “Programs, life cycles, and laws of software evolution”, *Proceedings of the IEEE* 68(9), 1980.

The empirical laws behind “software rots unless tended”.

https://doi.org/10.1109/PROC.1980.11805

Tomas Lindahl, “Instability and decay of the primary structure of DNA”, *Nature* 362, 1993.

Molecular evidence that life depends on continuous repair.

https://doi.org/10.1038/362709a0

Charles C. Branas et al., “Citywide cluster randomized trial to restore blighted vacant land and its effects on violence, crime, and fear”, *PNAS*, 2018.

A rare randomised test of maintaining places. Read the methods and limits, not just the headline.

https://pmc.ncbi.nlm.nih.gov/articles/PMC5866574/

National Vulnerability Database, CVE-2024-3094.

The official record of the xz backdoor.

https://nvd.nist.gov/vuln/detail/CVE-2024-3094

14 · CONCLUDING INSIGHT

The world does not stay built. It stays maintained, by people who succeed when you notice nothing. The next time something simply works — the tap, the bridge, the login screen, the friendship — try hearing it for what it is: not silence, but the sound of someone winning.

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