

## ORIGINAL RESEARCH ARTICLE

# The Cascading Effect of the Food–Fuel–Finance Triple Threat on Public Health Infrastructure: An Analytical Scoping Review and Comparative Synthesis

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## ABSTRACT

**Background:** Rising food insecurity, energy-price volatility and fiscal contraction are usually analysed as separate shocks. Health systems experience them together. This paper treats the three as a "triple threat" and examines how their combined pressure travels through the physical, human, informational and governance structures that make up public health infrastructure.

**Objective:** The paper aims to (i) map the evidence on the food, fuel and finance pathways to infrastructure degradation, (ii) review related research reviews and their outputs, (iii) compare evidence across regions and policy contexts, and (iv) propose an analytical framework and testable propositions.

**Methods:** A simplified scoping review was conducted, guided by PRISMA 2020 and PRISMA-ScR. A supplied corpus of 117 records was screened for thematic eligibility. Forty-two records were synthesised, and five were used for methodological and integrity guidance. The synthesis was triangulated with authoritative international reports and indexed peer-reviewed literature.

**Results:** The evidence converges on a cascade structure. The three shocks share transmission nodes (facilities, supply chains, workforce, information systems and governance), so their effects compound rather than add. Comparative evidence suggests that protective social spending, energy-resilient facilities and legally anchored financing separate systems that absorb shocks from those that fracture.

**Conclusion:** The paper proposes the Cascade Amplification Hypothesis and the Infrastructure Buffer Principle, and sets out a five-part resilience agenda. Equity, climate adaptation, digital governance and workforce protection are treated as core infrastructure, not peripheral concerns.

**Keywords:** *food insecurity; energy poverty; fiscal austerity; health systems resilience; syndemic; public health infrastructure; cascading risk; scoping review*

## 1. INTRODUCTION

Public health infrastructure is rarely noticed until it fails. It consists of the clinics, laboratories, cold chains, oxygen plants, surveillance systems, trained workers and legal mandates that allow a society to prevent illness as well as treat it. Over the past decade it has been tested by overlapping pressures that do not respect sectoral boundaries. The most recent global estimates indicate that about 673 million people, or 8.2% of the world's population, faced hunger in 2024. Around 2.3 billion experienced moderate or severe food insecurity, and roughly 2.6 billion could not afford a healthy diet [1]. Acute hunger is concentrated in crisis settings. The Global Report on Food Crises recorded 281.6 million people in 59 countries and territories facing high levels of acute food insecurity in 2023 [2]. Meanwhile, the health systems that should absorb the resulting disease burden are thinly protected. About 4.5 billion people were not fully covered by essential health services in 2021, and around two billion experienced financial hardship because of health spending [3].

Two further stressors sit beneath these figures. The first is energy. Modern care depends on continuous power for refrigeration, diagnostics, ventilation, sterilisation, lighting and digital records. Joint assessments by the World Health Organization, the World Bank and partner agencies estimate that roughly one billion people are served by health facilities without reliable electricity [4]. The second is finance. Public budgets absorb successive

shocks while carrying heavy debt-service obligations. UNCTAD estimates that about 3.3 billion people live in countries that spend more on net interest payments than on either health or education [5]. Food price inflation, fuel price volatility and fiscal contraction therefore act on the same institutions at the same time.

India shows how this plays out at national scale. Analyses of the national disease burden and of epidemiological transitions describe a country coping with infectious disease, non-communicable disease and nutritional deficiency all at once [6–8]. The National Family Health Survey (NFHS-5) documented a high prevalence of child stunting (35.5%), wasting (19.3%), and anaemia among children (67.1%) and women of reproductive age (57%) [7]. Sub-national work, including a socio-legal study of health disparities in Punjab, indicates that structural inequities and legislative gaps shape who is protected when systems come under strain [9]. Nutritional deprivation, energy insecurity and fiscal limits do not hit a uniform health system. They hit unequal systems, and they widen the inequalities already present.

The conceptual lens for this paper is the syndemic. The Lancet Commission on the global syndemic of obesity, undernutrition and climate change argued that epidemics which co-occur, share drivers and interact biologically and socially produce harm greater than the sum of their parts [10]. This paper extends that logic from disease to infrastructure. It asks whether concurrent food, fuel and finance pressures act on shared structural nodes, and whether doing so produces failure that is non-linear, delayed and partly irreversible.

The analysis addresses four questions:

- Through which mechanisms do food, fuel and finance shocks degrade public health infrastructure?
- What do existing reviews and empirical studies report about each pathway, and how do their findings compare?
- How do different regions and policy regimes differ in vulnerability and recovery?
- What analytical framework and policy agenda follow from the evidence?

The contribution is fourfold. First, the paper integrates three bodies of literature that are usually kept apart. Second, it offers a transparent, simplified scoping method suitable for rapid synthesis. Third, it advances two propositions that other researchers can test, challenge or cite. Fourth, it draws attention to evidence from Indian and South Asian settings that is often under-represented in global syndemic debates.

## **2. Conceptual Framework**

### **2.1 What counts as public health infrastructure**

A narrow definition of infrastructure covers buildings and equipment. A broader and more useful definition follows the health systems literature, in which infrastructure is the set of enduring capacities through which a system delivers quality care and protects populations. The Lancet Global Health Commission on high-quality health systems estimated that millions of deaths each year in low- and middle-income countries are amenable to health care, and that poor quality accounts for a large share of them [11]. The commission placed quality at the centre of system design, which implies that infrastructure failure shows up as lost quality long before facilities close.

Resilience adds a dynamic dimension. Kruk and colleagues defined a resilient health system as one in which health actors, institutions and populations can prepare for and respond to crises, maintain core functions and reorganise if conditions require [12]. A cross-country analysis of the COVID-19 response across 28 countries reached a related conclusion: resilience depends on early, adaptive and coordinated action supported by prior investment in capacities [13]. Infrastructure, on this reading, is the stored capacity that makes later adaptation possible. When food, fuel and finance shocks deplete it, the loss appears first as reduced flexibility and later as visible breakdown.

### **2.2 The triple threat and its social foundations**

Each leg of the triple threat has independent roots, but all three act through the social determinants of health. The WHO European review of social determinants documented how social position, income, education and living conditions shape health through gradients that cross borders and income levels [14]. Food, fuel and finance are

therefore not only external shocks. They are distributional mechanisms that translate pre-existing inequality into differential exposure.

Law and governance shape that translation. A policy-legal analysis of health legislation argues that statutory frameworks can strengthen national health systems by anchoring financing, entitlements and accountability [15]. The sociology of law offers a complementary view, in which law, society and social control are mutually constitutive and legal arrangements either reinforce or soften social hierarchies [16]. Work on corporate social responsibility and legislation adds that regulatory design influences whether commercial actors, including food, energy and pharmaceutical firms, behave ethically when markets are under pressure [17]. Infrastructure resilience therefore depends partly on legal architecture as well as engineering and budgets.

### 2.3 Five transmission nodes

The framework identifies five nodes through which the three shocks reach health outcomes. These are the points where separate pressures converge.

- **Physical facilities and energy.** Hospitals and clinics need power, water, fuel for transport and functioning equipment. Energy deficits compromise care at its point of delivery [4].
- **Supply chains.** Medicines, vaccines, therapeutic foods and consumables move through global networks exposed to geopolitical fragmentation. Analyses of US–China strategic competition describe a decoupling of global supply chains that raises uncertainty and cost for import-dependent systems [18].
- **Workforce.** Effective hospital leadership and management shape staff retention, morale and performance [19]. A systems-level analysis of burnout and bureaucracy among healthcare professionals highlights the mental health toll of administrative strain on the workers who hold the system together [20].
- **Information systems.** Digital transformation can improve hospital management [21], but access and outcomes in digital health vary across socioeconomic groups, so digital infrastructure can either narrow or widen inequity [22].
- **Governance and law.** Legal mandates, budgeting rules and institutional accountability determine whether shocks are cushioned or passed downward [15,16,17].

The cascade logic follows from this structure. A shock arriving at one node is manageable if the others are intact. Because food, fuel and finance converge on the same five nodes, the nodes degrade together, and the redundancy that normally protects the system disappears.

## 3. Methodology

### 3.1 Design and reporting guidance

The study is a simplified scoping review with an analytical synthesis. The reporting logic follows the PRISMA 2020 statement for transparent identification, screening and inclusion [23] and its scoping-review extension, PRISMA-ScR, which is designed to map evidence in fields where heterogeneity makes quantitative pooling inappropriate [24]. A scoping design suits this topic. The literature spans nutrition, energy studies, health economics, law and digital health, and no single outcome measure or effect size can be pooled across it.

The method is explicitly a streamlined adaptation. It is not a registered systematic review, and it makes no claim to exhaustive database searching. Guidance on applying PRISMA-ScR for emerging researchers emphasises systematic transparency, a clear research question, explicit eligibility criteria and a documented selection process [25]. A related methodological account describes PRISMA-ScR as a way of mapping research landscapes in a structured and auditable manner [26]. The present review follows these principles in miniature.

### 3.2 Eligibility and information sources

**Source corpus.** The primary corpus was a supplied reference list of 117 records covering health, climate, law, technology, labour, education, philosophy and other domains.

**Inclusion criteria.** A record was eligible if it substantively addressed at least one of the following:

- health conditions, health systems, hospital operations or health legislation;
- food and nutrition, or consumer food behaviour;
- climate hazards, displacement or environmental pressure affecting health;
- economic precarity, labour or supply chain dynamics relevant to health system financing and function;
- digital or algorithmic technologies in health care, and their equity consequences;
- psychosocial strain in crisis contexts.

**Exclusion criteria.** Records were excluded if their main subject fell outside these domains (for example, yoga philosophy, education accreditation, contract law or historical studies) and no plausible analytical link to health infrastructure under food, fuel or finance stress could be defended.

**Supplementary sources.** To avoid dependence on a single corpus and to add comparative quantitative data, the synthesis was triangulated with authoritative international reports, landmark indexed reviews and national surveys. These supplementary sources supplied global and regional indicators and established concepts such as syndemics, resilience and austerity effects.

### 3.3 Screening process in PRISMA terms

The identification and screening sequence is summarised in prose in place of a flow diagram.

- **Identification.** 117 records were identified in the supplied corpus.
- **Pre-screening removal.** One record was removed because its bibliographic information was incomplete and could not be verified. 116 records proceeded to screening.
- **Screening.** Titles and available bibliographic descriptors were screened against the criteria. 69 records were excluded as outside the thematic scope.
- **Eligibility.** 47 records were retained for fuller consideration.
- **Final allocation.** Five records were used only for methodological or research-integrity guidance and were not counted as evidence on the topic. 42 records were included in the thematic synthesis.

The principal limitation of this procedure is that screening was based on titles and bibliographic descriptors rather than on independent full-text appraisal. The synthesis therefore characterises the questions, scope and framing of the included studies and does not reproduce unverified numerical findings from them. Where the paper draws quantitative comparisons, it does so from the authoritative international and national sources, and it treats inferences from the supplied corpus as interpretive.

### 3.4 Synthesis approach and integrity

A narrative thematic synthesis was adopted. Included records were grouped by the transmission node or pathway they addressed. Findings were then compared for convergence, divergence and gaps, and the groups were interpreted through the cascade framework of Section 2.

Research ethics in social science concern accurate representation, transparency of method and proper attribution [27]. All claims in this paper are therefore expressed in original wording and attributed to their sources. Originality is also a matter of practice, and guidance on plagiarism detection and prevention stresses that rigorous paraphrase, correct citation and independent synthesis are the foundation of original scholarship [28,29].

## 4. Results of the Scoping Process

### 4.1 Characteristics of the included evidence

Of the 42 synthesised records from the supplied corpus, 36 were published in 2025, two in 2024 and three in 2026. One was undated. The concentration in 2025 means that the corpus reflects the most recent period of overlapping food, energy and fiscal stress. This is an advantage for currency but a limitation for long-run perspective.

The records are heterogeneous in design and publication venue. Several are broad narrative or "comprehensive analysis" papers. At least two identify themselves as systematic reviews, one on digital transformation in hospital

management [21] and one on trauma-related mental health among refugees and displaced persons in Africa [59]. Others take socio-legal or sociological approaches. Most appear in regional or multidisciplinary journals, so their evidentiary weight varies. Triangulation with indexed international literature was therefore essential.

#### 4.2 Thematic distribution

The 42 included records cluster into eight themes:

- Disease burden and epidemiological transition, with a South Asian emphasis.
- Nutrition, diet and food markets.
- Economic precarity, labour and platform work.
- Climate hazards, floods, urban pressure and displacement.
- Hospital operations, patient safety, facility design and workforce.
- Crisis leadership, trauma and psychosocial strain.
- Digital health, artificial intelligence and algorithmic equity.
- Law, governance and social justice.

Evidence on climate and flood impacts, on hospital operations and on digital health is relatively rich in the corpus. Direct empirical work on fuel and energy dependence of health facilities is sparse, and the paper relies on international assessments to fill that gap [4]. This gap is itself a finding. The energy leg of the triple threat is the least studied in the supplied literature relative to its importance for service continuity.

#### 4.3 Convergence across the evidence

Three convergent signals emerge. First, the studies consistently frame health outcomes as the product of structural conditions, with biomedical factors secondary. Second, they emphasise unequal exposure across socioeconomic, geographic and gender lines. Third, they treat infrastructure, whether physical, digital, human or legal, as the medium through which shocks are either buffered or transmitted. These signals support the framework used in the analysis below.

### 5. Related Research Reviews, Their Results and Perspectives

This section reviews prior research by pathway and summarises what each source reports and how much weight it can bear. Reviews are presented in groups corresponding to the three legs of the triple threat and to the intermediate conditions that link them to infrastructure.

#### 5.1 Food pathway: nutrition, affordability and supply shocks

The foundational evidence on nutrition and health comes from the Lancet series on maternal and child undernutrition. It concluded that undernutrition, including stunting, wasting and micronutrient deficiencies, is a major contributor to child mortality and to long-term developmental harm in low- and middle-income countries, accounting for a large proportion of deaths in children under five [30]. For the present analysis, the main implication is that food insecurity generates healthcare demand and weakens the immune defences that infrastructure is expected to support. The costs fall on health systems for decades.

Affordability is the mechanism through which price shocks become nutrition shocks. A global analysis of the cost of the EAT-Lancet reference diet found that a very large number of people could not afford it, with the burden concentrated in low-income regions [31]. Complementary work on relative caloric prices showed that nutrient-dense foods are systematically more expensive per calorie than starchy staples, and that this gap is pronounced at lower income levels [32]. Together these studies indicate that food price inflation does not reduce consumption uniformly. It shifts households toward cheaper, less nutritious diets, and the consequences appear as a double burden of undernutrition and diet-related disease.

Consumer-market and cultural perspectives add nuance. A comparative study of consumer behaviour in organic food markets shows how purchasing patterns respond to price, trust and perceived quality [33]. Such work implies that adaptive responses to price pressure are shaped by income and information, not only necessity. An analysis of the traditional sattvic diet and modern nutritional science shows that culturally embedded dietary systems can

contain nutritional wisdom that may support resilience if they are accessible and affordable [34]. These two perspectives are not direct measures of health system effects. They are useful as demand-side context for understanding how dietary adaptation evolves under stress.

Supply shocks operate at larger scale. An early assessment of COVID-19 risks to global food security highlighted that export restrictions and logistics disruption could trigger price spikes even when global stocks were adequate, and it argued for keeping trade open and protecting vulnerable consumers [35]. A review of the implications of the Russia–Ukraine conflict for global food supply chains described how disruption of grain, oilseed, fertiliser and energy flows transmitted shocks across interconnected markets [36]. Nutrition researchers warned that the war and associated price increases threatened to worsen child malnutrition, particularly wasting, unless protective measures were taken quickly [37]. Collectively these reviews show a consistent output: food price shocks are rapid, transnational and tightly coupled with energy and fertiliser markets, and the nutritional damage falls on the youngest.

**Appraisal.** The food-pathway literature is mature in epidemiology and in price analysis. It is weaker on the downstream question this paper asks, namely how malnutrition-driven demand and food-driven costs affect health facilities and workers. That link is usually assumed and rarely measured.

## 5.2 Finance pathway: crises, austerity and household exposure

The best-established evidence on finance and health comes from studies of economic crises. An empirical analysis of European data found that rising unemployment was associated with increases in suicide among working-age populations, and that stronger social protection and active labour-market programmes attenuated the health effects of economic downturns [38]. A broader review of the financial crisis and austerity in Europe documented that health outcomes depended on policy response: countries that cut deeply into health and social budgets experienced worse outcomes in some domains, including outbreaks of infectious disease and increased mental distress, whereas countries that protected social spending fared better [39]. The shared output is that economic crises do not deterministically damage health. The policy response mediates the effect.

Labour-market precarity is a second financial channel. A sociological study of the gig economy examines the erosion of worker identity and security under precarious labour arrangements [40]. Related work on platform poverty explores how algorithmic invisibility compounds social vulnerability among gig workers [41]. For public health, the relevance lies in coverage and risk. Workers outside formal employment often lack employer-based insurance, paid sick leave and predictable income, so they are exposed to both price shocks and health shocks. They are also less likely to seek preventive care when income is volatile.

Household out-of-pocket payment is the third channel. India's national health accounts show that out-of-pocket expenditure accounted for 47.1% of total health expenditure in 2019–20, a substantial decline from earlier years but still a large share [42]. Global monitoring reinforces the point that financial hardship from health costs remains widespread [3]. Where public financing is thin, households become the financing mechanism of last resort. Food and fuel price inflation then competes directly with health spending in the same household budget.

**Appraisal.** The finance literature offers the strongest causal designs, particularly the European crisis analyses. Its limitation for the present topic is context. Most of the best empirical evidence comes from high-income settings with stronger safety nets, so extrapolation to systems with high out-of-pocket dependence must be cautious.

## 5.3 Fuel and climate pathway: energy dependence and environmental feedbacks

Energy influences health infrastructure through two linked routes: reliability of supply at facilities, and the climate consequences of the fossil energy economy. On the first, the joint WHO–World Bank–IRENA–SEforALL assessment documented the scale of electricity access deficits in health-care facilities and their implications for service quality, setting out the case for reliable, preferably clean, power as a precondition of care [4]. Cold chain integrity, maternal and newborn services, surgery and diagnostics all depend on it, and the cost of fuel for backup generators falls on already strained facility budgets.

On the second route, the Lancet Countdown on health and climate change tracks how climate hazards translate into health risks. Its 2023 report presented evidence of rising heat exposure and climate-related pressure on food

security, noting that tens of millions more people experienced food insecurity in association with extreme weather and drought [43]. The implication for this paper is that fuel, food and climate are coupled: fossil fuel dependence feeds the climate hazards that disrupt agriculture and damage health facilities.

The health sector is itself an energy-intensive emitter. A global assessment estimated that health care accounted for roughly 4.4% of net global greenhouse gas emissions, which creates a paradox for decarbonisation policy [44]. A system that is a significant emitter is also exposed to the consequences of emissions, and strategies that reduce energy dependence within facilities may therefore serve both resilience and mitigation goals.

Urban form mediates these pressures. An environmental sustainability analysis of urban sprawl and local ecosystems points to the ecological costs of unplanned expansion, including loss of buffering landscapes and greater pressure on services [45]. Sprawl increases travel distances, fuel consumption and the exposure of populations to hazards. This is a spatial route by which fuel and health infrastructure interact.

**Appraisal.** The energy–health literature is dominated by agency assessments and climate-health tracking, with fewer controlled empirical studies of how fuel price changes affect facility performance. This is a clear research gap.

#### 5.4 Climate hazards, floods and displacement as stress multipliers

South Asia and the wider Asian region provide a natural laboratory for compound stress. A multi-part body of work on floods in Asian countries examines their causes, including climate change, urbanisation and socio-economic factors [46], their economic, social and environmental impacts and management [47], and their risk, vulnerability and adaptation dimensions [48]. A further paper explicitly analyses the health consequences of floods, covering direct and indirect effects, economic burden and the vulnerability of healthcare infrastructure [49]. Read together, these analyses support three interpretive conclusions. Floods are driven by both natural and human-made factors. Their burden is socially patterned. And health facilities are themselves exposed assets, vulnerable to physical damage, access cut-off and disruption of the supply of medicines and fuel.

Flooding is a plain example of how food, fuel and finance converge. It destroys crops and storage, which raises food prices. It disrupts roads and fuel supply, which raises transport costs. And it forces emergency public spending, which diverts funds from routine health budgets.

Displacement extends the same logic across space. An analysis of climate-induced migration and urban fragility in South Asia maps new frontiers of displacement and the pressures they place on receiving cities [50]. Displaced populations require rapid expansion of primary care, nutrition services and sanitation in places where infrastructure is already stretched. At the geopolitical level, an analysis of how environmental agreements are reshaping global power blocs suggests that climate governance is becoming entangled with strategic competition, which affects finance and technology flows to adaptation and health [51]. The psychological dimension is not trivial: a cross-cultural sociological perspective on climate anxiety and youth activism indicates that environmental stress carries mental health and civic implications, particularly for younger cohorts [52].

**Appraisal.** The flood and displacement literature is strong on descriptive breadth and on vulnerability framing. It is generally less strong on quantified health infrastructure outcomes, and it relies on secondary data. Nevertheless, it provides regionally grounded evidence that global syndemic discussions often lack.

#### 5.5 Hospital operations: safety, antimicrobial resistance, design and facility management

Hospital-level evidence shows how strain at the system level becomes harm at the bedside. A strategy-focused analysis of hospital-acquired infections frames infection prevention as central to patient safety [53]. Under resource stress, the conditions for infection control (reliable water, sterilisation, adequate staffing and consumables) are among the first to deteriorate. Antimicrobial resistance (AMR) amplifies the consequence. Research on AI-driven prediction of AMR patterns, integrating machine learning with genomic epidemiology, proposes data-driven approaches to precision antibiotic stewardship [54]. Such tools depend on laboratory capacity, data systems and stable electricity, which are themselves vulnerable nodes.

Facility design is a protective factor. An analysis of evidence-based environmental design and educational interventions argues that the built environment and staff and patient education can improve healthcare outcomes

[55]. Machine learning applied to smart facility management in healthcare hospitality environments suggests that predictive maintenance and resource optimisation can reduce waste and improve reliability [56]. The shared output is that well-designed and well-managed facilities are more robust to disruption, but the capital and digital investments required are less available to financially constrained systems.

**Appraisal.** This literature gives granular, operational insight and supports the claim that resilience can be engineered. The caveat is a selection effect: most examples describe what is feasible under adequate resources, and few address implementation under severe fiscal and energy constraints.

## 5.6 Crisis leadership, trauma and psychosocial strain

The human side of infrastructure is central. An analysis of crisis leadership in healthcare, focused on organisational learning from pandemic failures, argues that leadership practices and institutional learning determine how systems respond when shocks arrive [57]. A related paper on embedding trauma-informed care into healthcare leadership proposes a shift in organisational culture and patient outcomes by recognising trauma among both patients and staff [58]. A systematic review and meta-analysis on trauma-related mental health among refugees and internally displaced persons in Africa during conflict and crisis addresses prevalence and predictors of psychological harm in displaced populations [59]. Evidence on cancer-related stigma among tertiary students in Punjab shows that stigma shapes help-seeking and disclosure even where services exist [60]. Taken together, this literature suggests that crisis-era health systems must treat psychological safety as part of infrastructure, covering both the workforce and the community.

**Appraisal.** The psychosocial evidence is valuable because it captures costs that financial accounting misses. The challenge is that these costs are rarely measured within health budgets, so they are easily omitted from policy trade-offs.

## 5.7 Digital health, artificial intelligence and algorithmic equity

Digital and AI tools are increasingly proposed as buffers. An overview of artificial intelligence in diagnostic medicine considers how AI can support clinical diagnosis [61], and an analysis of redesigning patient engagement in AI-driven healthcare systems considers how patients' relationships with care are being reshaped [62]. These benefits are conditional. Work on algorithmic bias and social stratification argues that AI can reproduce and amplify inequality in digital societies [63]. In combination with the evidence on digital health equity [22] and digital transformation in hospitals [21], the cumulative lesson is that digital tools help most where connectivity, power, data governance and digital literacy are already adequate. In a triple-threat setting, they risk benefiting better-resourced institutions and populations first.

## 5.8 Social justice, labour and community dimensions

Several included studies broaden the lens from systems to society. An analysis of smart cities and the social divide examines spatial justice in the age of urban technology, which implies that investment in advanced infrastructure can deepen exclusion if distribution is not equitable [64]. A socio-legal study on educational disparities in India highlights structural inequities and the role of legislative frameworks [65]. Because education shapes health literacy and employment, such disparities feed directly into health vulnerability. A study of women's contribution to environmental protection in the global context points to gendered environmental stewardship [66], and a sociological look at invisible labour in the smart home shows the unpaid gendered work that absorbs shocks inside households [67]. A paper on quiet quitting examines work ethic and alienation in modern employment [68], which helps explain how burnout and disengagement can erode workforce capacity in stressed organisations. Civic sense is analysed as a catalyst for national development [69], which is relevant to community participation in public health. Studies of post-pandemic family relations [70] and of doomscrolling and mental fatigue in crisis media [71] show how prolonged crises reconfigure family life and cognitive load.

**Appraisal.** These sociologically oriented sources are not health-system studies in a narrow sense. Their value is that they identify the unpaid, informal and psychological buffers (household labour, civic norms, information environments) that absorb shocks before formal systems register them. Those buffers are finite.

## 5.9 Cross-review synthesis: what the reviews jointly show

Four conclusions follow from the cross-review comparison.

- **Convergence on mediation.** The strongest empirical reviews agree that outcomes depend on mediating policy and institutional choices [38,39]. Shocks set the risk, and institutions determine how much of it becomes harm.
- **Convergence on inequality.** Nearly every pathway shows disproportionate impact on poorer, rural, displaced, informal-sector and female populations [31,32,40,41,50,67].
- **Divergence on technology.** Technology-oriented sources emphasise opportunity [54,56,61], while equity-oriented sources emphasise risk [22,63,64]. The likely resolution is conditionality: technology is a force multiplier of existing capacity and governance quality.
- **A shared evidence gap.** Few studies measure the interaction of all three shocks on infrastructure. Most address one pathway or a pair, which motivates the integrative framework below.

## 6. Analytical Exposition: How the Cascade Operates

### 6.1 From separate shocks to a cascade

A cascade has four features: a trigger, a transmission structure, amplifying feedbacks and delayed consequences. In the food–fuel–finance context, the trigger can arise in any of the three domains, such as a harvest failure, a conflict-driven energy price spike or a sovereign debt squeeze. The transmission structure is the set of five nodes identified earlier. The feedback arises because damage at each node increases the burden on the others. Consequences are delayed because some effects, such as stunting, lost training years or deferred maintenance, mature over years.

Two analytical propositions follow, offered here as testable claims.

**Proposition 1: The Cascade Amplification Hypothesis.** When food, fuel and finance shocks coincide, the resulting damage to public health infrastructure is greater than the sum of damage from each shock separately, because the shocks share transmission nodes and deplete the same buffers.

**Proposition 2: The Infrastructure Buffer Principle.** The extent to which a shock becomes a health crisis is inversely related to the pre-shock stock of institutional, financial, energy and human buffers. Investment in buffers is therefore cheaper than post-crisis restoration.

These are consistent with established resilience thinking, in which prior capacity enables adaptation [12,13], and with syndemic reasoning, in which interaction multiplies harm [10]. They also fit the finance literature, in which protective policy responses reduced health damage from economic shocks [38,39].

### 6.2 The food channel into the infrastructure system

Food insecurity affects health infrastructure through demand, workforce and supply routes.

*Demand route.* Undernutrition increases susceptibility to infection and worsens recovery, which raises caseloads for primary care, paediatrics and maternal health [30]. In India, high prevalence of stunting, wasting and anaemia measured by NFHS-5 means that nutritional vulnerability is already a baseline condition [7]. A price shock lands on a population with little nutritional reserve, which increases the probability that a price rise translates into clinical need. Diet-related non-communicable disease is the second demand pathway. When healthy foods become unaffordable, households substitute toward cheaper, energy-dense options [31,32], so the burden shifts toward chronic conditions that require long-term care, a form of service that underfunded systems struggle to provide. This is consistent with the coexistence of undernutrition and diet-related disease emphasised in the syndemic framing [10] and in analyses of India's epidemiological transition [6,8].

*Workforce route.* Health workers are also consumers. Food price inflation reduces real wages, increases financial stress and encourages moonlighting or migration. The link between burnout, bureaucracy and mental health in healthcare professionals [20] suggests that economic strain adds to an already high psychosocial load. Quiet

quitting and disengagement [68] can be read as a behavioural expression of workplace alienation, which is more likely when pay falls behind living costs.

*Supply route.* Therapeutic and supplementary feeding programmes depend on procurement and logistics. Disruptions to global food and fertiliser markets [35,36] therefore threaten both the food supply of the general population and the specific commodities used in nutrition interventions. The warning that war-related price shocks threatened child nutrition [37] illustrates how global commodity disruption reaches clinic-level programmes.

### 6.3 The fuel channel into the infrastructure system

Fuel affects infrastructure through physical operation, mobility and cost.

*Operation.* Where grid supply is unreliable, facilities rely on diesel generators. The assessment of electricity access in health facilities makes clear that power enables core services [4]. When fuel prices rise, the cost of running backup power rises, forcing facilities to reduce operating hours, curtail refrigeration or defer non-urgent services. Because cold chains for vaccines and some medicines are extremely sensitive to interruption, fuel instability can produce unseen stock losses.

*Mobility.* Fuel costs drive transport costs for patients, ambulances, supply deliveries and community health workers. Sprawling urban forms increase this dependence [45]. In flood-prone regions, fuel scarcity combines with damaged roads to isolate communities [46–49].

*Coupling with food.* Energy prices feed into fertiliser, irrigation, processing and distribution costs. The review of the Russia–Ukraine conflict stressed this linkage across grain, oilseeds, fertiliser and energy markets [36]. Fuel shocks therefore often reach households as food price shocks, a clear example of coupling between two legs of the triple threat.

*The mitigation paradox.* Because health care is a notable emitter [44], and because climate hazards impose growing health costs [43], transition to cleaner, more reliable on-site energy offers a dual benefit. Facilities can lower exposure to fuel price volatility and reduce emissions, provided financing is available. Financing is where the third leg of the threat intervenes.

### 6.4 The finance channel into the infrastructure system

Finance affects infrastructure through public budgets, external obligations and household capacity.

*Public budgets.* When debt service absorbs a larger share of revenue [5], governments have less room to maintain, repair and expand facilities, or to pay and train staff. The European crisis evidence shows that the composition of fiscal adjustment matters: cuts to health and social protection were associated with worse outcomes in several domains than adjustments that protected them [38,39].

*Import dependence.* Many systems import medicines, diagnostics and equipment. Currency depreciation and supply chain fragmentation raise these costs [18]. The analysis of US–China decoupling highlights how strategic competition can reconfigure supply chains and increase uncertainty for dependent economies, with implications for health commodity procurement.

*Household capacity.* Out-of-pocket payments transfer financial risk to households [3,42]. When inflation reduces disposable income, patients delay care, which increases severity at presentation and makes eventual treatment more costly. Precarious workers face the sharpest version of this dynamic [40,41].

*Legal and governance buffers.* Health legislation can lock in financing priorities and entitlements [15], and the sociology of law explains why legal frameworks shape the distribution of social protection [16]. Regulatory design for commercial actors affects how food, energy and pharmaceutical markets behave under stress [17]. Where such legal anchors are weak, budget pressure is more likely to translate into discretionary cuts to health.

## 6.5 Interaction effects: why the whole exceeds the parts

The Cascade Amplification Hypothesis rests on four interaction mechanisms.

- **Shared-node congestion.** All three shocks stress the workforce, supply chains and facilities at once. A facility that could manage a food-related surge in paediatric admissions with a stable power supply and full staffing may fail when power is unreliable and staff are absent or burned out.
- **Buffer depletion.** Household savings, public reserves, informal care labour and goodwill are finite. Sequential shocks draw them down, so each later shock hits a more fragile base. The unpaid gendered labour that cushions households [67], and the civic and community capital that supports collective action [69], are examples of buffers that can be exhausted.
- **Feedback to demand.** Infrastructure degradation raises morbidity, and morbidity increases demand on degraded infrastructure. Hospital-acquired infection and AMR illustrate this loop, since weak infection control increases complications, and complications lengthen stays and consume more resources [53,54].
- **Information degradation.** Crisis conditions overload both formal and informal information systems. Digital transformation can strengthen management [21], but unequal digital access [22] and algorithmic bias [63] may skew resource allocation. At the individual level, constant exposure to crisis media is associated with cognitive overload and mental fatigue [71], which can undermine health-seeking behaviour and public trust.

## 6.6 Node-by-node analysis

**Facilities.** Facility resilience combines location, design and power. Flood evidence indicates that infrastructure in hazard-prone areas is exposed to both direct damage and access loss [49]. Design strategies can improve outcomes [55], and smart facility management can help optimise resources [56]. However, these gains require capital, which the finance channel constrains.

**Supply chains.** Supply chains move food, fuel and medicines, so they are the physical link between the three shocks. Geopolitical decoupling [18] and conflict-driven disruption [36] increase lead times and costs. Systems with diversified sourcing and strategic stockpiles are better placed, but stockpiles require upfront financing and storage energy.

**Workforce.** Health workers carry the system's adaptive capacity. Leadership quality shapes how stress is distributed and managed [19,57]. Trauma-informed leadership [58] and attention to burnout [20] are not merely welfare measures, since they conserve the scarcest infrastructure of all. In crisis-affected regions, the psychological toll of conflict and displacement [59] can affect both patients and the staff who serve them.

**Information systems.** Digital tools can support triage, diagnostics and surveillance [54,61], and patient engagement can be redesigned through them [62]. Yet unequal telemedicine outcomes across socioeconomic groups [22] and algorithmic stratification [63] warn that digital infrastructure must be built with equity as a design requirement, or it will widen gaps in precisely the populations most hit by the triple threat. Smart-city investments illustrate how technology-led development can generate spatial injustice if distribution is neglected [64].

**Governance and law.** Governance determines allocation. Statutory frameworks, accountability mechanisms and the sociolegal environment shape whether shocks are absorbed collectively or passed on to individuals [15,16]. The socio-legal study of health disparities in Punjab argues that legislative gaps contribute to inequity [9], and parallel analysis of education indicates how structural inequities are reproduced through weak frameworks [65]. These point to governance as the node with the greatest leverage, because it conditions the response at every other node.

## 6.7 Time structure and irreversibility

The cascade has a temporal profile that differs from the shock itself. Price spikes occur in weeks, but nutritional damage in early childhood is largely irreversible, and the workforce attrition and deferred maintenance that follow fiscal squeeze may take a decade to reverse [30,39]. Climate disasters compress this time structure further, adding abrupt physical destruction to slow degradation [46–49]. Policy that responds only to the visible, short-term phase of the cascade will systematically underestimate the long-term burden.

## 6.8 An Indian illustration

India provides a concrete case in which the framework can be applied. A large share of the population carries nutritional vulnerability [7]. The disease burden spans communicable, non-communicable and nutritional conditions, with identified epidemiological transitions [6,8]. Out-of-pocket spending remains high despite recent declines [42]. Climate hazards, especially floods, regularly strain infrastructure and displace people [46–50]. Sub-national inequities, as in Punjab, reveal how legislative gaps compound structural disadvantage [9]. A triple threat landing on this configuration would meet limited household buffers, exposed facilities and uneven governance capacity. The country is also making substantial progress in some areas, including the decline in out-of-pocket share [42] and expanding digital health platforms [21,22], which shows that trajectory is not fixed. The determining factor will be whether protective investments keep pace with accumulating risk.

## 7. Comparative Research Evidence

### 7.1 High-income austerity versus low-resource vulnerability

The European crisis experience supplies the clearest natural experiment on finance and health. Countries that sustained social protection and labour-market programmes saw attenuated health effects, whereas those with deep cuts experienced worse mental health outcomes and some infectious disease resurgence [38,39]. The key comparative lesson is that policy choice was decisive even among relatively wealthy health systems with established universal coverage. In low-resource settings, the baseline buffers are thinner, so the policy margin is narrower and the penalty for error is higher. About 4.5 billion people lack full coverage of essential services globally [3], which implies that in much of the world there is little universal coverage to protect.

### 7.2 India and sub-national contrasts

At national level, India's trends show partial improvement alongside persistent burden. Out-of-pocket spending's share of total health expenditure fell to 47.1% in 2019–20 [42], yet nutritional indicators such as child stunting at 35.5% and anaemia affecting 57% of women of reproductive age [7] remain very high. The interplay between epidemiological transition [8], disease burden [6] and region-specific disparities [9] indicates that national averages hide significant variation. Comparing Punjab-level socio-legal analysis [9] with the national picture illustrates the importance of sub-national governance in determining resilience.

### 7.3 Conflict-affected and displacement settings

Crisis settings represent the extreme end of the spectrum. The food crisis data show hundreds of millions in acute food insecurity, concentrated in conflict and climate-affected contexts [2]. The systematic review on trauma-related mental health among refugees and displaced persons in Africa [59] indicates that psychological harm is an integral part of the burden. In such contexts, the health infrastructure challenge is multi-layered: facilities may be damaged, supply lines cut, staff displaced and financing dependent on volatile external aid. In contrast to the European case, where the question is how to design austerity, the question here is how to sustain minimal functionality.

### 7.4 South Asian hazard exposure

Flood analyses across Asian countries establish that hazard exposure, urbanisation and socio-economic vulnerability combine to produce large, recurrent impacts [46–49]. Displacement analysis for South Asia indicates that these impacts extend into urban fragility [50]. Compared with conflict settings, the hazard is more predictable and recurrent, which makes adaptation investment more tractable. The comparative implication is that where risk is recurrent, resilience financing offers a high return, whereas in acute conflict the priority is access and continuity.

### 7.5 Global indicators in summary

Global indicators describe the aggregate stakes. Hunger affects 8.2% of the world's population [1]. Acute food crises affect 281.6 million people in 59 countries and territories [2]. Roughly one billion people are served by facilities without reliable electricity [4]. About 3.3 billion people live in countries spending more on interest than

on health or education [5]. Almost two billion experience financial hardship from health costs [3]. These numbers are not independent. The same countries and communities often appear in several, which is precisely the pattern predicted by the cascade framework.

## 7.6 What the comparison suggests

Four comparative regularities emerge.

- **Policy mediation is robust across income levels.** Protective social spending reduced harm in high-income crises [38,39], and legal anchoring of health financing is advocated for national systems [15].
- **Buffers matter more in poorer settings.** Thin buffers imply that each shock translates more directly into loss of services.
- **Hazard predictability changes the strategy.** Recurrent hazards, as with South Asian floods, reward preparedness investment [49], while acute conflict requires continuity-of-care and mental health support [59].
- **Digital solutions are context-dependent.** Digital health shows promise where access and governance are adequate [21,61], but evidence of unequal outcomes [22] and algorithmic bias [63] implies that benefits do not automatically reach the most vulnerable.

## 8. Analysis from Different Perspectives

A credible analysis needs to test the framework against several disciplinary viewpoints. Each perspective below highlights something the others miss.

### 8.1 Economic perspective

Economists will note that the three shocks interact through relative prices, exchange rates and fiscal space. Food and fuel inflation reduces real incomes, and public sector wage lag can accelerate workforce loss. High debt service restricts countercyclical spending [5]. The European evidence suggests that fiscal consolidation that cuts health and social protection can be self-defeating, since it raises later health costs and reduces productive capacity [38,39]. The economic argument for buffers is therefore one of avoided cost. Prevention is cheaper than the compounded cost of delayed care, particularly for child nutrition, where harm is largely irreversible [30].

### 8.2 Health systems perspective

From a health systems standpoint, the triple threat is a stress test of the building blocks: service delivery, workforce, information, medical products, financing and governance. Quality and resilience frameworks [11,12,13] suggest that systems with strong primary care, diversified supply and adaptive management cope better. The cascade view adds that resilience must be assessed in combination. A system that is strong on workforce but dependent on unreliable power may still fail.

### 8.3 Equity and human-rights perspective

The equity perspective stresses that the cascade is not random. It follows the contours of disadvantage along income, geography, gender, informality and displacement [31,32,40,41,50,67]. Smart-city and digital developments show that new infrastructure can recreate old exclusions [22,64]. Educational and socio-legal disparities likewise feed health vulnerability [9,65]. On a rights-based reading, governments have obligations to protect minimum core levels of health and nutrition even under fiscal strain, which makes the design of austerity a matter of legal and ethical duty as well as economics.

### 8.4 Legal and regulatory perspective

Legal analysis points to the importance of statutory entitlements, budget protection and regulatory oversight [15,16]. The sociology of law warns that formal rules can mask uneven enforcement and unequal access to justice [16]. Corporate responsibility legislation can nudge food, energy and pharmaceutical firms toward ethical conduct in crises [17], although the strength of such nudges depends on enforcement. The legal perspective also

highlights gaps: where legislation does not clearly assign responsibility for continuity of essential health services during energy or supply failures, institutions improvise, and improvisation favours the well-connected.

### 8.5 Environmental and climate perspective

The environmental perspective frames the triple threat as partly an outcome of ecological stress. Climate change influences agricultural yields, energy systems and disaster frequency [43,46,48]. Urban sprawl compounds exposure and fuel dependence [45]. Women's roles in environmental protection point to the importance of inclusive environmental governance [66]. Climate anxiety among young people shows that environmental stress carries an emotional load that may shape future civic and health behaviour [52]. Global environmental agreements, in turn, are reshaping power relations that govern climate finance [51]. For health infrastructure, this implies that adaptation and mitigation should be integrated into facility planning, supported by the observation that health care is itself a significant emitter [44].

### 8.6 Technological perspective

Technologists emphasise the potential of AI and digital tools for diagnostics, AMR surveillance, facility management and patient engagement [54,56,61,62]. A balanced view recognises that these tools depend on data quality, connectivity and electricity, and that algorithms may embed bias [63]. The reality is that technology reduces some vulnerabilities while creating new dependencies. Smart infrastructure must be assessed against equity of benefit and against its own resilience to the same energy and financing shocks it is meant to mitigate [22,64].

### 8.7 Workforce and psychosocial perspective

This perspective treats staff well-being as infrastructure. Leadership style, organisational learning, trauma-informed practice and burnout management all affect whether a system can sustain effort under stress [19,20,57,58]. The wider literature on alienation and disengagement [68] and on the cognitive burden of crisis media [71] suggests that psychological depletion is a systemic risk. Household and family restructuring after pandemics [70] indicates that the effects extend beyond the workplace into home life, where much unpaid care is provided [67].

### 8.8 Political-economy and ethical perspective

A political-economy reading asks who benefits and who bears costs. Supply chain realignment and strategic competition [18,51] shape which countries can secure medicines, energy and finance on favourable terms. Domestic political economy decides whether health budgets are protected. The ethical dimension includes transparency, honesty in research and recognition of the limits of evidence [27]. It also includes the duty to attend to those least visible in data, such as informal workers [41] and stigmatised patients [60].

### 8.9 Reconciling the perspectives

The perspectives do not conflict at the level of diagnosis. All identify the same vulnerable nodes. They differ in the levers they emphasise: prices and fiscal rules for economists, building blocks for systems analysts, entitlements for lawyers, adaptation for environmentalists, tools for technologists and care for workforce scholars. The integrative implication is that no single lever suffices, and that a package of coordinated interventions is required.

## **9. Policy and Practice Implications: A Five-Part Resilience Agenda**

The analysis suggests the following agenda. Each element targets a node or interaction identified above.

**1. Protect the financing floor through law.** Statutory ring-fencing of core health and nutrition spending, together with explicit rules for countercyclical protection, addresses the finance channel and the governance node [15,16]. The comparative evidence from Europe supports protecting social and health spending during downturns [38,39]. Debt-service burdens suggest that international debt relief and concessional financing for health are also relevant [5].

**2. Energy-secure every critical facility.** Reliable, ideally clean, on-site power should be treated as a core clinical input [4]. Cleaner energy lowers exposure to fuel price shocks and also reduces the sector's emissions footprint [44]. Facility design and smart management can improve efficiency and reliability [55,56].

**3. Make nutrition a health-system function.** Because food insecurity generates both immediate and long-term demand [30], health systems should integrate nutrition surveillance and support into primary care, and coordinate with social protection to maintain access to healthy diets [31,32]. Surveillance of price shocks should trigger pre-planned protective measures, as the war-related warnings argue [37].

**4. Invest in people and psychological safety.** Workforce strategies should include fair remuneration, leadership development, trauma-informed practice and burnout prevention [19,20,57,58]. Attention to mental health among displaced and crisis-affected populations should be built into service design [59].

**5. Build equitable, hazard-aware digital and physical systems.** Digital health should be designed and audited for equity [22,63]. Facilities in flood-prone and climate-exposed regions should be sited, hardened and supplied with continuity plans [46–49], and displacement-related surges should be planned for in receiving cities [50]. Participation by civil society and communities can strengthen legitimacy and uptake [69].

**Cross-cutting enablers.** Implementation depends on integrity of evidence. Open reporting, transparent methods and ethical practice are prerequisites for credible policy learning [25–27].

## **10. Limitations**

Several limitations qualify the conclusions.

First, the method is a simplified scoping review and not a full systematic review. There was no registered protocol, no multi-database search and no formal risk-of-bias scoring. The supplied corpus was the principal source, and supplementary literature was selected purposively. Selection bias is therefore possible.

Second, screening of the supplied corpus relied on titles and bibliographic descriptors. The synthesis characterises the scope and framing of those studies and does not independently verify their numerical findings. Inferences drawn from them are interpretive.

Third, the supplied corpus is heavily concentrated in recent publications from a limited set of regional and multidisciplinary outlets, and several of its records are broad narrative analyses instead of primary empirical studies. This restricts the weight they can bear, which is why triangulation with indexed international sources was used.

Fourth, evidence on the energy leg of the triple threat is relatively thin. The conclusions about fuel rely more on agency assessments than on controlled studies.

Fifth, the propositions advanced here are conceptual. The Cascade Amplification Hypothesis and the Infrastructure Buffer Principle require formal empirical testing through longitudinal, multi-country data on facility functionality, prices, financing and health outcomes.

Sixth, quantitative indicators are drawn from different years and methodologies and should be treated as indicative of scale, not precisely comparable.

## **11. CONCLUSION**

This paper argued that food insecurity, energy instability and fiscal constraint should be analysed as a coupled system acting on public health infrastructure. The reviewed evidence shows that the three shocks converge on the same nodes (facilities, supply chains, workforce, information systems and governance) and that their combined effect is likely to exceed the sum of their parts. Food-related malnutrition raises demand and erodes long-term human capital [30–32]. Fuel instability undermines the operation and mobility on which care depends [4,36,44]. Financial constraint reduces the capacity to respond and shifts risk to households [3,5,38,39,42].

Comparative evidence provides grounds for cautious optimism. Policy responses mediated the health damage from economic crises in Europe [38,39], and similar logic applies elsewhere: legal anchoring, protected budgets, energy-secure facilities, supported workers and equity-conscious technology all reduce transmission. The Indian and South Asian evidence shows both the scale of exposure, from nutritional vulnerability to recurrent floods and sub-national inequity [6–9,46–50], and the scope for progress.

The Cascade Amplification Hypothesis and the Infrastructure Buffer Principle offer a basis for future work. Researchers can test whether simultaneous shocks produce super-additive infrastructure loss, and whether pre-shock buffers explain differences in outcome. For decision-makers, the central message is that resilience is built in advance, node by node, because once the shocks have converged the available options are fewer and more expensive. Treating food, fuel and finance as one connected problem is a precondition for protecting the systems that protect health.

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