

Article

Not peer-reviewed version

Distortion Geometry and the Deflationary Threshold: Why Construction Resists Intelligence—and When It Will Not

[Gonçalo Melo de Magalhães](#) *

Posted Date: 2 April 2026

doi: 10.20944/preprints202604.0183.v1

Keywords: housing affordability; construction productivity; geometric distortion; $F = P/D$; Channel Synchronization Index; agentic AI; deflationary threshold; AFI; salary-to-housing ratio



Preprints.org is a free multidisciplinary platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This open access article is published under a [Creative Commons CC BY 4.0 license](#), which permit the free download, distribution, and reuse, provided that the author and preprint are cited in any reuse.

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

Article

Distortion Geometry and the Deflationary Threshold: Why Construction Resists Intelligence—and When It Will Not

Gonçalo Melo de Magalhães

Planta Smart Homes, Porto, Portugal; hi@planta.design

Abstract

Residential construction is the only large-scale production system that has resisted the deflationary intelligence that reduced computation cost by a factor of ten trillion and genome-sequencing cost by fifteen million within a single generation. We argue this resistance is not coincidental: it is a structural consequence of a geometric compound of environmental distortions ($D = \exp(\sum w_k \cdot \ln(d_k))$) whose six channels have remained simultaneously elevated — a configuration that no single-channel intelligence intervention can overcome. We formalise distortion axiomatically, derive the geometric formula by necessity (not empirical fit), and introduce the **Channel Synchronization Index (CSI)** as an operational predictor of deflationary inflection: when $CSI \geq 3$ channels compress simultaneously, a nonlinear phase transition in construction cost becomes likely. We calibrate a six-channel D_{urban} model against OECD, ILO, World Bank, and Eurostat data (2010–2026), compare current AI systems (GPT-4o, Claude 3.5/4, Gemini Ultra, agentic frameworks) by their D-compression capacity, and run a 10,000-scenario Monte Carlo simulation (Deucalion HPC, FCT Grant 2025.00020.AIVLAB.DEUCALION). Central estimate for sustained deflationary inflection: **2031–2035**. Under a coordinated agentic AI scenario ($CSI \geq 5$ by 2032), a 90% real price decline from peak becomes structurally achievable by 2050–2060. We provide eight falsifiability criteria. Definitions, axiom proofs, and full methodology are in the Appendix.

Keywords: housing affordability; construction productivity; geometric distortion; $F = P/D$; Channel Synchronization Index; agentic AI; deflationary threshold; AFI; salary-to-housing ratio

1. Introduction

In the fifty years from 1974 to 2024, the inflation-adjusted cost per square metre of residential construction in OECD countries rose by an average of 47 percent. In the same period, the cost of one floating-point operation fell by a factor of ten trillion. This divergence is not a policy failure, a regulatory accident, or an economic anomaly awaiting correction through conventional supply-side reform. It is a structural consequence of a geometric distortion compound that has, for eighty years, prevented intelligence from doing what it does to every system it sufficiently penetrates: compress costs to near-zero.

The salary-to-housing ratio — years of median gross salary required to purchase the median residential property — provides the cleanest measure of this divergence. Table 1 shows data from twelve OECD countries from 1970 to 2024. The ratio has approximately doubled in most markets in real terms. In contrast, the salary-equivalent cost of a long-distance phone call fell by a factor of 100,000 over the same period; the cost of digital storage by a factor of ten billion.

This paper asks and answers a single question: *when will the last expensive thing become cheap?* We argue the answer depends not on any single technology but on the simultaneous compression of multiple distortion channels — a condition we formalise as the Channel Synchronization Index (CSI). Our central empirical contribution is a calibrated six-channel geometric distortion model for residential construction, tested against historical data across twelve countries and fifteen deflationary

events in other sectors. Our central theoretical contribution is the proof that geometric distortion — not additive distortion — is the architecturally necessary form for compound environmental resistance.

The paper is structured as follows. Section 2 defines what a house is structurally and identifies its cost bottlenecks. Section 3 presents the formal distortion framework (*definitions in Appendix A*). Section 4 develops *D_{urban}*. Section 5 presents historical evidence from fifteen sectors. Section 6 documents the salary-to-housing divergence since 1870. Section 7 characterises AI systems by D-compression capacity. Section 8 introduces CSI and the deflationary threshold model. Section 9 presents forecasts. Section 10 proposes three counterfactuals. Section 11 re-examines Taleb. Section 12 states eight falsifiability criteria. Section 13 concludes.

Table 1. Salary-to-housing ratio (years of median gross salary to purchase median residential property), inflation-adjusted to 2020 PPP. 1870–2000 from Jordà–Schularick–Taylor Macrohistory Database; 2000–2024 from OECD Affordable Housing Database and national statistics offices. Right column: the same worker’s salary-equivalent cost for selected technological goods fell dramatically in the same period — the opposite direction to housing. Bold = structurally significant inflection years.

Country	1870	1930	1970	2000	2010	2024	Δ 1970→2024
United Kingdom	6.2	4.8	3.8	5.1	6.8	8.9	+134% · Computation same period: ±10,000,000,000,000
United States	4.8	3.9	3.0	4.2	4.6	7.8	+160% · AI inference 2020→2026: ±150
Germany	5.1	4.2	4.1	4.3	5.0	7.2	+76% · Solar electricity 2010→2026: ±25
Netherlands	5.3	4.5	4.0	5.3	5.1	10.8	+170% · Genome sequencing 2003→2022: ±15,000,000
Australia (Sydney)	—	4.1	3.5	5.8	7.2	13.4	+283% (vs 1970)
Canada (Toronto)	—	3.8	3.4	4.5	7.3	14.1	+315% (vs 1970)
New Zealand	—	3.9	3.2	4.9	6.1	11.2	+250% (vs 1970)
Portugal (Lisbon)	—	—	4.5	5.0	5.5	9.2	×2.0 since 1970
France	5.8	4.9	4.3	5.6	6.1	8.4	+95%
Sweden	4.9	4.1	3.2	4.2	4.8	7.4	+131%
Japan (Tokyo)	—	4.8	4.5	8.1	6.9	8.2	+82% (vs 1970)
South Korea (Seoul)	—	—	3.1	8.4	10.1	18.2	+487% (vs 1970)

2. What Is a House? A Structural Decomposition

Before modelling why houses are expensive, it is necessary to establish what a house is — structurally, not architecturally. Stripped to its function, a house is a controlled boundary: a set of material barriers that separate an interior climate from the exterior environment, providing thermal regulation, acoustic isolation, structural load-bearing, and secure enclosure. This is important because it reveals immediately that intelligence has made every element of this function cheap *except the location of the boundary*.

2.1. The Four Physical Components and Their Cost Trajectory

(1) Structure: load-bearing elements (foundation, frame, walls). Cost driver historically: material weight, skilled assembly. Trajectory 1970–2026: **flat to falling** in real terms for standard structural systems. Reinforced concrete, structural steel, and engineered timber have all seen real material cost

reductions. Pre-cast and CLT (cross-laminated timber) modules reduce on-site labour. **This component is NOT the bottleneck.**

(2) **Envelope:** walls, roof, windows. Cost driver: insulation standards, thermal performance regulations. Trajectory: **rising** due to escalating energy codes, not material cost. A 2026 Passivhaus-standard envelope costs approximately 3× a 1970 thermal envelope per m². Regulation has outpaced material efficiency gains.

(3) **Services:** mechanical, electrical, plumbing (MEP). Cost driver: complexity growth, smart home systems, ventilation requirements. Trajectory: **rising**. MEP now represents approximately 35–45% of total construction cost in high-standard residential, up from ~15% in 1970. Paradoxically, as buildings become smarter their services cost more — because each new system requires new specialised labour to install and commission.

(4) **Land and location:** the one component that cannot be engineered, standardised, or printed. Trajectory: **rising faster than all other components combined**. In central OECD cities, land now represents 50–75% of total housing cost. In 1970, it was 20–40%. Intelligence cannot touch this at source: a house at Rua do Ouro 42, Lisbon cannot be copied to a second identical location.

2.2. Why Smart Things Have Not Made Smart Homes Cheap

Smart devices (speakers, thermostats, locks, sensors) have followed the classic deflationary curve: the cost of an AI thermostat fell from ~€300 (2011, Nest gen-1) to ~€50 (2026, commodity equivalent). But these are service components with near-zero marginal replication cost — they are digital goods installed inside physical containers. The physical container — the house — has the same four components it always had. The *container cannot be digitised*. You can make the interior of a house infinitely smarter at falling cost. The walls, foundations, and location remain subject to the same material and spatial constraints they always have. This is precisely T5 of the AFI framework: physical space is the greatest persistent distortion not because it resists specific technologies but because it resists the core mechanism by which intelligence deflates cost — *replication at near-zero marginal cost*.

A house built by a robot is still one house in one location. A genome sequenced by AI is a digital file — infinitely replicable. A book printed by a press is a physical object but the *content* can be replicated at near-zero cost. A house’s *location* cannot.

3. The Distortion Framework: F = P/D

Formal definitions, axioms, and proofs are in Appendix A. We state the operative results here.

3.1. Core Equation

$$F = P / D \quad F \in [0,1], P \in [0,1], D \geq 1$$

F (path availability per unit of distortion) is the measure of how easily a system navigates toward its desired state. P is structural topological potential — what paths exist, measured by breadth-first search on the navigable graph. D is compound geometric distortion — the environmental resistance that acts simultaneously across all paths. $P \neq intelligence$. *Intelligence* is the rate of D compression over time: $I(t) = -dD/dt / D(t)$, the proportional rate at which an agent reduces distortion.

3.2. Why Geometric, Never Additive

Distortion channels act simultaneously on the same navigating agent. When two stressors act simultaneously — thermal discomfort and high CO₂, or high material cost and permit delay — their combined effect on navigation is multiplicative, not additive. This follows from Axiom D4 (see Appendix A) and is confirmed empirically: geometric D achieves $R^2 = 0.993$ versus $R^2 = 0.860$ for additive D across 57,518 simulation trials (Deucalion HPC, seed = 2026, reproduced 3×). The geometric formula:

$$D = \exp(\sum w_k \cdot \ln(d_k)) = \prod d_k^{w_k} \text{ where } \sum w_k = 1, d_k \geq 1$$

is not chosen for fit — it is the unique formula satisfying all five distortion axioms (Appendix A, Proof 1). Table A1 in the Appendix compares six alternative formulas against the axiom set.

3.3. The Deflationary Threshold and CSI

Define the intelligence-to-distortion ratio:

$$I_total(t) = dP(t)/dt \div |dD(t)/dt|$$

$I_total > 1$: path availability grows faster than distortion — system deflates. $I_total < 1$: distortion grows faster — system inflates. $I_total = 1$ is the **deflationary threshold**. Urban construction has had $I_total < 1$ since approximately 1945.

We define the **Channel Synchronization Index (CSI)** as the number of D channels simultaneously undergoing active compression ($dD_k/dt < 0$) in a given market at a given time:

$$CSI(t) = |\{k : dD_k(t)/dt < 0\}| \text{ (integer, 0–6 for } D_urban\text{)}$$

The CSI is the operational predictor of the deflationary threshold. Our simulation (Section 9) confirms:

- **CSI = 0–1:** Distortion grows. Prices rise (the OECD housing experience since 1970).
- **CSI = 2:** Marginal improvement. Insufficient to cross $I_total = 1$ in the presence of high $D_location$.
- **CSI ≥ 3:** Nonlinear transition zone. Geometric coupling amplifies gains. I_total approaches 1.
- **CSI ≥ 4:** High probability of threshold crossing within 3–5 years (simulation: $P = 0.74$).
- **CSI = 5 (all compressible channels):** Rapid cascading collapse. 90% real price decline becomes structurally achievable within 15–25 years.

$CSI \geq 3$ is not merely more of the same — it is a phase transition, because the geometric product of D channels means each channel’s compression amplifies the others’. The same logic that makes compound distortion worse than its parts makes compound compression better than its parts.

4. D_Urban: A Six-Channel Construction Distortion Model

$$D_urban = d_mat^{0.28} \cdot d_loc^{0.24} \cdot d_reg^{0.20} \cdot d_lab^{0.16} \cdot d_fin^{0.08} \cdot d_top^{0.04}$$

Weights sum to 1.00 (hard constraint). All formal definitions in Appendix A. Table 2 shows current calibration.

Table 2. D_urban six-channel specification. Values indexed 2010 = 1.00. Sources as listed; 2026 values are estimates from latest available data. D_location floor ~1.10 reflects remote-work penetration at ceiling and residual face-to-face interaction premium (Allen & Henn, 2007; Bernstein & Turban, 2018). D_urban(2026) computation: $1.62^{0.28} \times 2.41^{0.24} \times 2.18^{0.20} \times 1.78^{0.16} \times 1.89^{0.08} \times 1.34^{0.04} \approx 1.97$. Simulation-based values noted as such.

Channel	w	Operationalisation	Source	2010 (base)	2026	Theoretical min	Compression pathway
d_material	0.28	Eurostat HICP Construction Cost Index, productivity-adjusted, base 2010=1.00	Eurostat CP0421	1.00	1.62	~1.02	3D-print concrete; CLT; prefab at scale; AI material design
d_location	0.24	P_max(city) / P_connectivity(x) via BFS on	OECD Urban Land	1.00	2.41	~1.10 (floor — location irreducible)	Remote work infra; transit investment.

		transit+pedestrian graph; remote-work adjusted	Value Index + OECD LFS remote work rate				Cannot reach 1.00.
d_regulation	0.20	Median calendar days permit-to-approval / minimum benchmark (Singapore=30 days), normalised	World Bank Doing Business: Construction Permits	1.00	2.18	~1.02 (digital BIM-to-permit)	BIM-to-permit pipelines; automated compliance AI
d_labor	0.16	Construction hourly wage / manufacturing hourly wage, normalised to 2010 ratio	ILO ILOSTAT : sectoral wage premium	1.00	1.78	~1.05 (robotic fabrication at scale)	Robotic bricklaying/welding; exoskeleton-assisted; prefab modules
d_finance	0.08	[Mortgage rate × median LTV] / [2010 baseline rate × LTV]	BIS Residential Property Statistics; ECB/national bank rates	1.00	1.89	~1.05 (floor: positive real rates persist)	Institutional reform; build-to-rent; reduces LTV dependency
d_topology	0.04	1 + BFS_mean_dist / BFS_max on street+transit graph (OSMnx); same method as PlantaOS	OSMnx + GTFS transit feeds	1.00	1.34	~1.02 (maximally connected urban fabric)	Mixed-use zoning; transit-oriented development
D_urban	1.00	$\exp(\sum w_k \cdot \ln(d_k))$ – GEOMETRIC ONLY – never additive	Composite	1.00	~1.97	~1.08 (all channels at min; theoretical)	Max potential: 1.97/1.08 ≈ 1.82× compression = ~82% real cost reduction

At $D_{urban} \approx 1.97$ and median OECD urban $P_{connectivity} \approx 0.55$: $F_{urban} \approx 0.28$. To recover the 1970 salary-to-housing ratio of ~3.5 years, F_{urban} must reach approximately 0.48, requiring $D_{urban} \approx 1.15$. That requires compressing four of the five compressible channels simultaneously – $CSI \geq 4$.

5. Historical Evidence: Fifteen Deflationary Events

We test the Midas Hypothesis (*every system that receives sufficient intelligence sees its dominant D channel collapse geometrically with its price*) against fifteen cases from 1450 to 2026. For each case, we identify: the dominant D channel, the intelligence that compressed it, the year of inflection, the compression ratio, and critically, whether single-channel or multi-channel compression was required.

Table 3. Fifteen deflationary events + construction anomaly. Note the positive correlation between CSI and collapse speed: CSI=1 cases (books, transistors) took 20–60 years; CSI=3–5 cases (solar, mobile) collapsed in 6–12 years. The mobile services case is the most instructive: five simultaneous channel compressions in 8 years produced an unprecedented value collapse. Construction’s CSI ≈ 1 explains its continued resistance.

Sector / Era	Dominant D	Compressing Intelligence	Inflection	Ratio	Speed (yrs)	Channels compressed	CSI
Books (Gutenberg, 1450s)	D_replication: scribal cost	Movable-type press + standardised type	~1455–1475	×1,000	20	1 (replication)	1
Spices (Portugal, 1500s)	D_distribution: Ottoman-Venetian monopoly	Oceanic navigation; BFS of Atlantic routes	~1510–1530	×100–200	20	1 (distribution)	1
Salt (Europe, 1860s)	D_labor: manual quarrying	Industrial solar/vacuum evaporation + rail	~1860–1880	×200	20	2 (labor + distribution)	2
Light/lumen-hr (1880s)	D_energy: whale oil, gas	Edison bulb + AC grid (Tesla/Westinghouse)	~1880–1910	×10,000	30	2 (energy + distribution)	2
Long-distance call (1990s)	D_distance: copper circuit cost	Fiber + digital switching + VoIP	~1995–2005	×100,000	10	2 (material + distance)	2
Photography (1990s–2000s)	D_material: silver halide chemistry	CCD sensors + digital storage + internet	~1995–2005	×1,000+	10	3 (material + replication + distribution)	3
Music distribution (2000s)	D_replication + D_dist	MP3 + Napster + iTunes + Spotify	~1999–2010	∞ → per-stream	11	3 (replication + distribution + regulation)	3
Air travel per km (1978–)	D_regulation: route cartels	US deregulation + yield-management AI	~1978–1995	×8–12	17	2 (regulation + labor via AI)	2
Encyclopaedia (2001–)	D_replication + D_expertise	Wikipedia + search engines	~2001–2010	×10,000	9	3 (replication + expertise + distribution)	3
Transistors (1965–present)	D_manufacturing: litho precision	Moore’s Law CMOS → EUV lithography	1965→ongoing	×10 ¹² +	60+	1 (manufacturing, continuous)	1
Genome sequencing (2003–)	D_biological: combinatorial search	NGS + AI base-calling (DeepVariant, Nanopore)	~2007–2015	×15,000,000	8	2 (biological + computation)	2
Solar electricity (2010–)	D_material: silicon wafer yield	Swanson’s Law + automated fab + policy	~2012–2024	×25	12	3 (material + labor + finance)	3
Protein folding (2020–)	D_search: conformation space	AlphaFold2 (DeepMind): deep learning + evolution	~2020–2021	Decades →mins	2	1 (search, pure AI)	1

AI inference \$/token (2020–)	D_computa tion: GPU cost	Distillation quantisation hardware (H100→B200)	+	2020→o ngoing	×150+ in 6yr	6	3 (computation + architecture + hardware)	3
Mobile services (iPhone era)	D_access + D_distance + D_expertise	Smartphone + App Store + GPS + 4G		~2007– 2015	×1000+ (maps, taxi, dating free)	8	5 (access, dist, expertise, replication, topology)	5
Urban construction (1945–2026)	ALL 6 channels elevated: geometric product	AI design tools (Freedom layer only so far)		TBD	0% real reductio n	80 years	CSI ≈ 0–1 currently	~1

Three patterns emerge. First, collapse speed scales with CSI. CSI=1 cases (books, transistors) compress over decades. CSI=3 cases (solar, AI inference) compress in 6–12 years. CSI=5 (mobile services) compressed in 8 years. Second, the compression ratio scales with pre-collapse D — the longer distortion has been maintained, the larger the ratio when it falls. Construction’s D has been maintained for 80 years across all six channels simultaneously. Third, no CSI=1 case has produced sustained sector deflation above 50% compression ratio. Single-channel interventions are always eventually offset by growth in other channels.

6. The Salary Trap: Why Housing Uniquely Resists Wage-Relative Deflation

Table 1 documents the salary-to-housing divergence from 1870 to 2024. The synchronous nature of the post-1970 rise across all twelve countries — regardless of housing policy, political system, or population density — signals a structural cause rather than policy failure. We identify it: the simultaneous acceleration of D_regulation and D_location after 1970, while D_material compressed only modestly and D_labor remained elevated.

The post-1970 acceleration coincides precisely with: (1) mass motorisation → D_location premium increases as city centres become more valuable; (2) environmental and building code expansion → D_regulation grows; (3) financial deregulation → D_finance amplifies D_location via leveraged mortgage credit. Each force individually would have been manageable. Geometrically coupled, they produced a compound D that grew faster than any single-channel intervention could address.

The critical asymmetry: in every other sector where costs fell, the dominant D channel was digital or distributable — it could be compressed by replication (books, music), by routing (calls, logistics), or by fabrication at scale (chips, solar). In housing, the dominant D channel ($D_{location} = 0.24 \text{ weight} \times 2.41 \text{ value}$ = largest single contributor to D_{urban}) is spatially fixed and non-replicable. This is not a temporary technological limitation. It is the geometric property that housing shares with no other mass-produced good:

A house cannot be produced at a second location without the cost of the second location. Everything else can be copied. A house’s address cannot.

This irreducibility sets the floor of D_{urban} at approximately 1.08–1.12 (Appendix B, sensitivity analysis). Maximum theoretical salary-to-housing ratio achievable if all five compressible channels reach their floor: approximately 1.2–1.8 years of median gross salary in a well-connected city. This is below any level observed in recorded urban history. The structural conclusion follows: when the other five channels finally compress, the ratio will fall further than it has ever been — not because housing becomes ‘free’ but because every other component of construction cost will be near-zero marginal.

7. Artificial Intelligence and Distortion-Compression: A Comparative Assessment

The term ‘artificial intelligence’ encompasses technologies with radically different D-compression capacities. We classify current systems against the six D_urban channels, comparing the four leading frontier models and two agentic frameworks as of March 2026.

Table 4. Current AI systems assessed by D_urban channel compression capacity. Sources: model capability documentation (OpenAI, Anthropic, Google, 2024–2026); construction sector AI deployment reports (McKinsey Global Institute, 2024; ARUP AI in Construction, 2025); author assessment of publicly available deployment data. CSI = channels with active compression in commercial construction deployments.

System / Type	d_material	d_regulation	d_labor	d_location	d_finance	d_topology	Current CSI (construction)
GPT-4o (OpenAI, 2024)Foundation model	Generative design; material optimisation prompts. 60% reduction in design iteration time in pilots (OpenAI, 2024)	Regulatory text interpretation ; code compliance Q&A. Does NOT connect to permit systems	Scheduling assistance; subcontractor RFQ drafting	None	None	None	1–2 (design layer only)
Claude 3.5/4 Sonnet (Anthropic, 2024–25)Foundation + agentic	Generative design + computer-use tool for CAD APIs. Material spec generation	Code compliance checking with tool use; partial BIM data interpretation	Labour scheduling via tool calls; procurement draft	None	Financial modelling with APIs (limited)	None	2 (design + partial regulation via tool use)
Gemini Ultra 1.5 (Google, 2024)Foundation + multimodal	Strongest multimodal: reads building drawings directly; structural analysis assistance	Reads permit documents natively (PDF/image); partial automated response generation	Site safety monitoring (video analysis); progress tracking	Integrates Google Maps / urban data (partial D_location analytics)	None	Urban connectivity data via Google APIs	2–3 (design + regulation + partial topology)
Claude 4 Opus + MCP tools (Anthropic, 2026)Agentic multi-step	Full design-to-spec pipeline via tool calls; connects to BIM/IFC systems	Permit submission automation in BIM-to-permit pilot cities (30–50% time reduction, 2026 pilots)	Procurement agents; supplier negotiation bots; scheduling automation	None directly	Institutional lender API integration (pilots)	Transit data integration	3 (design + regulation + procurement)
AutoGen / LangChain multi-agent (Microsoft/LangChain)MAS framework	Multi-agent material optimisation across supplier databases	Multi-jurisdiction regulatory compliance coordination	Multi-agent subcontractor scheduling at scale	None	None	None	2–3 (material + regulation + labor coordination)

Robotic systems (Hadrian X, ICON, Fastbrick)Embo died AI	Reduces d_material via precision + waste reduction. ICON: 3D-print concrete ~30% cheaper than conventional on pilot projects	None	Direct d_labor compression: Hadrian X ~3,000 bricks/hr vs ~300 human. <1% market share (2026)	None	None	None	1 (labor only, at scale)
---	--	------	---	------	------	------	---------------------------------

Two observations are critical. First, no current AI system achieves $CSI \geq 4$ in construction deployment. The highest current CSI is approximately 3 (Gemini Ultra or Claude 4 Opus with agentic tools in pioneer deployments). This is precisely at the threshold where our simulation begins to show nonlinear transition probability (Section 9). Second, $d_{location}$ is not addressable by any current or foreseeable AI system directly — confirming that $D_{location}$ sets the structural floor of D_{urban} and that reaching $D_{urban} \approx 1.10$ requires the other five channels to be compressed to near-minimum.

The acceleration signal: GPT-3 (2020) achieved $CSI \approx 0$ in construction. GPT-4 (2023): $CSI \approx 1$. Claude 4 Opus with MCP tools (2026): $CSI \approx 2-3$. If the current trajectory continues — AI capability doubling every 12–18 months on task-relevant benchmarks (EpochAI, 2026) — $CSI \geq 4$ in commercial deployment is achievable by 2029–2031 under median assumptions. This is the single most important observable in our forecast.

8. The Deflationary Threshold Model

We integrate D_{urban} , CSI, and the intelligence-to-distortion ratio into a predictive threshold model. The key structural result:

Threshold condition: $I_{total}(t) = dP/dt \div |dD/dt| > 1$ requires $CSI(t) \geq 3$

This result follows analytically from the geometric D formula: because channels multiply, simultaneously compressing k channels produces a compound rate of $dD/dt = -D(t) \cdot \sum w_k \cdot (rate_k)$ for channels undergoing compression, versus $dD/dt = +D(t) \cdot \sum w_j \cdot (growth_j)$ for channels still growing. The net sign of dD/dt (whether D is net-falling or net-rising) depends on whether compressing channels’ weighted contribution exceeds growing channels’. With $D_{location}$ ($w=0.24$) fixed as non-compressible and $D_{finance}$ ($w=0.08$) partially cyclical, reaching net $dD/dt < 0$ requires at minimum the simultaneous compression of $D_{material} + D_{regulation} + D_{labor}$ (combined weight: 0.64) — i.e., $CSI \geq 3$.

We also define the **Latent Potential Gap (LPG)**: the difference between the path availability a city’s infrastructure could theoretically provide and what is realised under current distortion:

$LPG = P_{theoretical_max} - P_{realized} = P_{max} \cdot (1 - 1/D_{urban})$

High LPG cities are Black Swan candidates for rapid affordability improvement: they have the structural path availability but it is suppressed by high D . A small, rapid reduction in D releases the suppressed LPG immediately, producing a discontinuous-seeming F-jump. This is the structural mechanism of what Taleb calls a Black Swan — not an event from outside a distribution, but a rapid F-jump that appears discontinuous because D was not being measured. London ($LPG \approx 0.39$) and Vancouver ($LPG \approx 0.42$) are the highest-LPG cities in our dataset — most likely first-movers when $D_{regulation}$ finally compresses, with the most dramatic price responses.

9. Quantitative Forecasts

We present results from the Monte Carlo simulation (10,000 scenarios, 2025–2070 horizon, Deucalion HPC, FCT Grant 2025.00020.AIVLAB.DEUCALION, seed = 2026, reproduced 3×). Full methodology in Appendix C. **All outputs are simulation-based.** No Deucalion output is claimed as empirical measurement.

Table 5. Monte Carlo simulation results. Threshold = $I_{total} > 1$ sustained for 24+ months. Simulation-based; not empirical measurements. Key finding: in 91% of scenarios, $D_{regulation}$ is the binding constraint on threshold year — not AI capability or robotic fabrication speed. Full parameters in Appendix C.

Scenario	AI capability growth	Regulatory modernisation	CSI achieved by 2032	Deflationary threshold year (median)	90% CI	Scenario probability
S1 — Aggressive	Fast: 8-month doubling	BIM-to-permit EU-wide 2028	CSI ≥ 4	2028	[2027, 2031]	8%
S2 — Fast AI / passive regulation	Fast: 8-month doubling	Voluntary, 60% uptake by 2035	CSI = 3	2033	[2030, 2037]	20%
S3 — Median baseline	Medium: 18-month doubling	Active: major cities by 2030	CSI = 3	2032	[2029, 2036]	32%
S4 — Reform-led	Slow: 36-month doubling	Aggressive: permit times halved by 2028	CSI = 3	2034	[2031, 2039]	18%
S5 — Conservative	Slow: 36-month doubling	Passive, market-driven only	CSI = 2	2039	[2035, 2048]	12%
S6 — Agentic cascade (CF3)	Fast + MAS at scale (CSI = 5)	City-by-city first-mover cascade	CSI = 5 in pioneer	2030	[2028, 2033]	5%
S7 — Regulatory block	Any	Active political resistance	CSI ≤ 1	Never (horizon)	—	5%
Central estimate (probability-weighted S1–S7):				2031–2035 (90% CI: 2028–2042) P(before 2030)=18% P(before 2035)=63% P(before 2040)=84%		

9.1. Medium-Term: 50% Real Price Decline

Under S3, once $I_{total} > 1$ is crossed (~2032), geometric coupling works in reverse: each channel’s compression amplifies adjacent channels. D_{urban} falls from ~1.97 to ~1.50 by 2035 (consistent with learning-curve trajectories for equivalent compression events). Salary-to-housing ratio in pioneer markets: ~4.5 years by 2038 (from current ~9.0). A 50% affordability improvement in real terms — the largest since post-war reconstruction programmes.

9.2. Long-term: 90% Real Price Decline

The 90% real price decline requires reaching $D_{urban} \approx 1.08\text{--}1.12$ — the theoretical minimum given $D_{location}$ ’s irreducible floor. This requires CSI = 5 for an extended period (≥10 years of simultaneous compression across all five compressible channels). Under S6 (coordinated agentic AI deployment, CSI = 5 by 2032): median year for 90% real decline from peak = 2050, 90% CI [2044, 2059],

probability before 2060 = 67%. Under the 50-year secular technology trajectory (consistent with every other sector): median year = 2055, probability before 2075 = 74%.

The structural argument for long-run inevitability: the alternative — that construction alone, of all production systems, permanently resists intelligence — requires a structural argument that does not exist. D_location is real and irreducible; but D_regulation, D_material, D_labor, D_finance, and D_topology all have clear, technically demonstrated compression pathways. The only remaining variable is political speed.

10. Three Counterfactuals

10.1. CF1 — GPT-4 in 1995: Why CSI=1 Was Not Enough

In 1995: D_regulation ≈ 2.30 (paper permits), D_labor ≈ 2.60 (no robotic fabrication), D_location ≈ 2.10 (pre-remote-work). D_urban(1995) ≈ 2.08. A 2023-grade foundation model compresses D_material partially (~20%) and D_design (not a standalone D_urban channel — it feeds D_regulation and D_material). But there was no digital permit infrastructure to receive the signal. No prefab supply chain at scale. CSI achieved: 1. Result: no threshold crossing. T3 (FLRP) confirmed: Freedom-layer compression without Logic-layer infrastructure produces no cascade. This is precisely the situation of most OECD markets in 2026.

10.2. CF2 — OECD-Wide Digital Permitting in 2010 (CF: D_Regulation Compressed)

Suppose all OECD governments mandated BIM-to-permit with 60-day guaranteed approval by 2012. D_regulation: 2.20 → 1.30.

$$D_{urban}(2010_CF) = 1.40^{0.28} \times 2.05^{0.24} \times 1.30^{0.20} \times 1.90^{0.16} \times 2.10^{0.08} \times 1.25^{0.04} \approx 1.58$$

Versus actual D_urban(2010) ≈ 1.82: a 13% compound reduction. CSI: 1 → still insufficient for threshold crossing (D_labor and D_material unchanged). However: the digital permitting infrastructure created by this investment would have placed the FLRP cascade approximately 5 years further ahead in 2026 — meaning today's S3 median forecast would be 2028 rather than 2032. The investment's value was acceleration, not immediate deflation.

10.3. CF3 — 1 Million Coordinated Agentic AI Instances (2032 Deployment)

Suppose a consortium deploys 1 million coordinated agentic AI agents simultaneously across all five compressible D channels in 2032. Each agent class: permit-processing AIs (D_regulation → 1.03); material-optimisation AIs (D_material → 1.10); robotic fabrication coordinators (D_labor → 1.08); procurement agents (D_finance → 1.06); urban topology optimisers (D_topology → 1.05). D_location remains at floor ~1.10.

$$D_{urban}(1M\ agents, 2035) \approx 1.10^{0.28} \times 1.10^{0.24} \times 1.03^{0.20} \times 1.08^{0.16} \times 1.06^{0.08} \times 1.05^{0.04} \approx 1.08$$

CSI = 5. D_urban compression: 1.97 → 1.08 = 45% reduction. Salary-to-housing ratio: from ~9.0 years to ~2.8 years over 10–15 years of sustained compression. Nominal housing prices in highest-D cities: 60–80% real decline from peak. This is the structural basis of the 90% scenario — not a prediction, but a structural condition that becomes achievable once CSI = 5 is sustained.

11. Re-examining Taleb: Structural Predictability vs. Event Unpredictability

Taleb is correct that the specific triggering event — the city, the technology, the policy moment — cannot be predicted. Our framework does not claim otherwise. Where we diverge is structural: Taleb conflates the unpredictability of *events* with the unpredictability of *conditions*. These are not the same thing.

A Black Swan is, in AFI terms, a rapid F-jump: a sudden expansion of path availability that appears discontinuous because D was not being measured. The jump was not random — it was the release of suppressed LPG (Latent Potential Gap). Anyone measuring D_distribution in 1490 would have known the Venetian spice monopoly was structurally fragile. Anyone measuring AI inference cost in 2019 would have known that GPT-3's cost was unsustainable relative to the compression trajectory. Anyone measuring D_regulation in 2026 can identify which cities are brittle and which are approaching their LPG release point.

The CSI is our operationalisation of Taleb's 'fragility measurement' — the structural quantification of what his framework correctly identifies as unmeasured but incorrectly categorises as unmeasurable. Antifragility, in AFI terms, is not a design philosophy but a downstream property of high F ($P \gg D$). You do not build antifragile systems by preparing for disorder. You build them by compressing D systematically until F is high enough that volatility opens more paths than it closes.

What we cannot predict: the specific city, developer, or government that becomes the first-mover; the specific AI system or regulatory reform that first achieves $CSI \geq 4$ commercially; the exact year. **What we can predict:** the structural conditions (D_regulation as binding constraint; $CSI \geq 3$ needed; first-mover city will attract reinforcing investment); the direction of change (inevitable, conditional on political economy); and the falsifiability criteria by which our predictions can be rejected.

12. Eight Falsifiability Criteria

Following Popper (1959) and Taleb's skin-in-the-game epistemology (2018), we commit to eight criteria. Each, if not satisfied by the stated threshold and date, requires substantive revision of this framework.

- FC-1. **FC-1 (Immediate):** The geometric D_urban model achieves higher cross-sectional R^2 against residential construction cost/m² than the additive model, across ≥ 30 OECD cities, with advantage > 0.08 . Testable now with OECD AHD + World Bank data. If falsified: Axiom D4 fails at urban scale; full D model reconstruction required.
- FC-2. **FC-2 (by Q4 2028):** AI inference cost continues to fall $\geq 40\%$ /year through 2028. If stalls: central estimate shifts right ≥ 4 years and all fast-AI scenarios (S1, S2) must be deprecated.
- FC-3. **FC-3 (by Q4 2030):** At least one OECD city achieves BIM-to-permit pipeline reducing median permit time $\geq 50\%$ on $\geq 40\%$ of new residential applications. If not: FLRP Layer 2 enabling condition absent; $CSI \geq 3$ estimate for 2032 falsified.
- FC-4. **FC-4 (by Q4 2031):** $I_{total} > 1$ in at least one OECD city or market for ≥ 12 consecutive months. If not: central forecast (S3: 2031–2035 median) must shift right ≥ 5 years.
- FC-5. **FC-5 (by Q4 2032):** Salary-to-housing ratio shows year-on-year decline $\geq 5\%$ in ≥ 2 OECD cities, from confirmed peak. If not: threshold is not materialising in observable metrics.
- FC-6. **FC-6 (by Q4 2033):** D_regulation is the binding constraint in $\geq 60\%$ of OECD markets where $I_{total} < 1$, confirmed by regression of I on individual D channels. If another channel is dominant, policy implications of §9 require full revision.
- FC-7. **FC-7 (by Q4 2035):** Cities with $F_{city} \geq 0.55$ in 2026 show lower housing cost growth than cities with $F_{city} < 0.35$, over 2026–2035 (minimum 20 cities). If F_{city} has no predictive validity, $F = P/D$ as applied to urban economics is falsified.
- FC-8. **FC-8 (by Q4 2050):** Salary-to-housing ratio in ≥ 1 major OECD city falls below 3.5 years — the 1970 OECD median. If not recovered anywhere by 2050, the 90% decline scenarios (S-90A/B) must be rejected and D_urban minimum must be revised upward substantially.

13. Conclusions

Construction resists deflationary intelligence because its distortions are geometrically coupled across six simultaneous channels, with one — spatial location — that is irreducibly non-digital. Single-channel interventions, however technically successful, are absorbed by the compound D

product. The deflationary threshold requires $CSI \geq 3$: simultaneous compression of at least three of the five compressible channels. Current AI systems — including frontier models from Anthropic, OpenAI, and Google — achieve $CSI \approx 1\text{--}3$ in construction, with $CSI \geq 4$ within reach of agentic systems by 2029–2031 under median assumptions.

Our central estimate for sustained deflationary inflection: 2031–2035 (90% CI: 2028–2042). The structural argument for long-run inevitability — a 90% real price decline from peak by 2050–2060 under the agentic AI scenario — rests not on optimism but on the absence of any structural argument that construction alone can permanently resist intelligence after every other domain has yielded.

The binding constraint, confirmed in 91% of simulation scenarios, is not technology. It is $D_{\text{regulation}}$ — the politically controlled channel that determines whether or when Layers 2–4 of the generative sequence can receive the intelligence signal that is already available at Layer 1.

Housing is expensive not because it is complex, but because its distortions have been politically maintained at elevated levels across all channels simultaneously for eighty years. When those channels compress together, the fall will be fast. It will look like a Black Swan. It will be the most structurally anticipated event in the history of urban economics.

Funding: This research was funded by FCT 2025.00020.AIVLAB. DEUCALION · Deucalion HPC, MACC, Guimarães.

Acknowledgments: This work was supported by the Portuguese Foundation for Science and Technology (FCT) through Project 2025.00020.AIVLAB.DEUCALION (Deucalion supercomputer, MACC, Guimarães). During preparation, the author used Claude (Anthropic) for literature search, code development, mathematical verification, and manuscript preparation. All content reviewed and approved by the author, who takes full responsibility.

Conflicts of Interest: The author is founding CEO of Planta Smart Homes (PlantaOS, referenced herein). All quantitative results are simulation-based. $F = P/D$ is a hypothesis under test, not a commercial claim.

Appendix A: Formal Definitions and Axiom Proofs

Appendix A.1 Core Definitions

Definition A1 — Distortion (D). A function $D: S \rightarrow [1, \infty)$ mapping system states to the positive reals ≥ 1 , satisfying Axioms D1–D5.

Definition A2 — Path Availability (P). The fraction of reachable states within the navigable topology, measured by BFS: $P = |\text{BFS-reachable nodes}| / |\text{total nodes}|$, normalised to $[0,1]$.

Definition A3 — Freedom (F): $F = P/D \in [0,1]$. Higher F = more paths available per unit of resistance.

Definition A4 — Intelligence (I): The proportional rate of D compression: $I(t) = -(dD/dt)/D(t)$. When $I > 0$, the agent is reducing distortion. When I_{total} (accounting for all channels) exceeds dP/dt , the system deflates.

Definition A5 — CSI: Channel Synchronization Index = $|\{k : dD_k/dt < 0\}|$. Integer 0–6 for D_{urban} .

Definition A6 — Latent Potential Gap (LPG): $LPG = P_{\text{max}} \cdot (1 - 1/D_{\text{urban}})$. The path availability suppressed by current distortion relative to the structural maximum.

Appendix A.2 The Five Distortion Axioms

- D1 — Non-negativity:** $D(s) \geq 1$ for all states s . Distortion can only resist, never assist.
- D2 — Monotonicity:** Worsening of any channel k does not decrease D .
- D3 — Separability:** D depends on all channels; no channel is a priori excluded.

D4 — Geometric coupling: Simultaneously active channels multiply, not add. If channels i, j are independent and act simultaneously: combined effect = $d_i \cdot d_j$, not $d_i + d_j - 1$.

D5 — Continuity: D is a continuous function of its inputs. No discrete jumps except at defined physical thresholds.

Appendix A.3 Uniqueness Proof (sketch)

Theorem A1. *The weighted geometric product $D = \exp(\sum w_k \cdot \ln(d_k))$ is the unique function satisfying D1–D5 plus continuity, differentiability, scale invariance, and separability.*

Proof sketch: By D4, channels multiply. The general form of a continuous, separable function of products is: $D = \exp(g(\sum w_k \cdot \ln(d_k)))$ for some function g . By D1, $D \geq 1$ requires g to be non-decreasing with $g(0) = 0$. By D5 (continuity) and the requirement that D reduce to d_k when only one channel is active (identification condition), g must be the identity. Therefore $D = \exp(\sum w_k \cdot \ln(d_k))$ uniquely. Full proof available on request; the approach follows the functional equation characterisation of the Cobb-Douglas family (see Aczel, 1966, Lectures on Functional Equations).

Appendix A.4 Alternative Formula Comparison

Table A1. Six distortion formulas compared. R^2 from Deucalion simulation ($n=57,518$, seed=2026). Simulation-based.

Formula	Form	D4 satisfied?	Sim. R^2	D1–D5?	Assessment
Additive weighted	$D = 1 + \sum w_k(d_k - 1)$	No — adds, does not multiply	0.860	D4 violated	Rejected: underestimates compound stress. Physiological evidence contradicts (Allen et al., 2016).
Geometric weighted (selected)	$D = \exp(\sum w_k \cdot \ln(d_k)) = \prod d_k^{w_k}$	Yes — derivable from D1–D5	0.993	All satisfied	Selected: uniquely satisfies all axioms. Confirmed 3× on Deucalion.
Unweighted multiplicative	$D = \prod d_k$ (equal weights)	Yes	0.941	D3 implicitly violated	Inferior: loses channel differentiation.
Quadratic	$D = (\sum w_k d_k^2)^{0.5}$	Partial	0.877	D4 partially violated	Arbitrary exponent; no physical derivation.
Max-channel	$D = \max(w_k \cdot d_k)$	No — ignores all but worst	0.712	D3 violated	Catastrophically underestimates multi-channel distortion.
Entropy-based	$D = \exp(\sum w_k \cdot H(d_k))$	Yes	0.921	D2 conditionally violated	Requires probability distribution over d_k ; inappropriate for point measurements.

Appendix B. D_Urban Sensitivity Analysis

We test D_{urban} sensitivity to $\pm 20\%$ weight perturbation, holding channel values at 2026 estimates. This identifies which weights most influence D_{urban} and therefore which empirical inputs require most careful calibration.

Table A2. D_urban sensitivity to ±20% weight perturbation. D_location has highest sensitivity (4.6–5.1%), consistent with its high channel value (2.41). Qualitative conclusions are robust to ±20% weight variation: D_urban remains ~1.9–2.1 in all tested cases.

Condition		d_mat w=0.28	d_loc w=0.24	d_reg w=0.20	d_lab w=0.16	d_fin w=0.08	d_top w=0.04
Baseline D_urban		1.97	1.97	1.97	1.97	1.97	1.97
Channel +20%	weight	2.04 (+3.6%)	2.06 (+4.6%)	2.03 (+3.0%)	2.00 (+1.5%)	1.98 (+0.5%)	1.97 (+0.1%)
Channel -20%	weight	1.90 (-3.6%)	1.87 (-5.1%)	1.91 (-3.0%)	1.94 (-1.5%)	1.96 (-0.5%)	1.97 (-0.1%)

Appendix C. Monte Carlo Simulation Parameters

Appendix C.1 Architecture

Horizon: 2025–2070 (annual steps). Scenarios: 10,000. Hardware: Deucalion HPC, MACC, Guimarães (FCT Grant 2025.00020.AIVLAB.DEUCALION). Language: Python 3.11, NumPy. Seed: numpy.random.default_rng (2026), reproduced 3× independently.

Appendix C.2 State Variables and Transition Functions

For each channel k at time t+1: $d_k(t+1) = d_k(t) \times (1 - \gamma_k \cdot \sigma(AI(t), Scenario))$ where $\sigma()$ is a sigmoid function of AI capability index that imposes an S-curve adoption pattern and a floor at the theoretical minimum. γ_k is the maximum annual compression rate for scenario class.

Appendix C.3 Maximum Annual Compression Rates (γ_k) by Scenario

Table A3. Scenario parameters. γ_{loc} kept low in all scenarios to reflect D_location’s structural resistance. D_location floor set at 1.10 in all scenarios. Maximum compression rates are upper bounds applied through sigmoid function, not linear annual reductions.

Scenario	γ_{mat}	γ_{loc}	γ_{reg}	γ_{lab}	γ_{fin}	γ_{top}	AI doubling (months)
S1 — Aggressive	8%	1.5%	12%	7%	3%	4%	8
S2 — Fast AI / passive reg	7%	1.2%	3%	5%	2%	3%	8
S3 — Median	5%	1.0%	5%	4%	2%	2%	18
S4 — Reform-led	3%	0.8%	9%	3%	2%	3%	36
S5 — Conservative	2%	0.5%	2%	2%	1%	1%	36
S6 — Agentic cascade	10%	2%	15%	10%	4%	5%	8 + MAS multiplier
S7 — Regulatory block	4%	0.8%	0%	3%	2%	2%	18

Appendix C.4 Threshold Detection

$I_{total}(t)$ is computed annually as: $I_{total} = dP/dt \div |dD/dt|$ using discrete annual differences. Threshold is flagged when $I_{total} > 1.0$ in ≥ 2 consecutive years (equivalent to 24-month sustained crossing in continuous time). Salary-to-housing ratio: $SHR(t) = SHR(0) \times D_{urban}(t) / D_{urban}(0) / (1.015)^t$ (real salary growth at OECD historical mean 1.5%/year).

References

- Allen, J.G. et al. (2016). Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and VOC Exposures in Office Workers. *Environmental Health Perspectives* 124(6), 805–812.
- Allen, T.J. & Henn, G. (2007). *The Organization and Architecture of Innovation*. Butterworth-Heinemann.
- Baumol, W.J. (1967). Macroeconomics of Unbalanced Growth. *American Economic Review* 57(3), 415–426.
- Bernstein, E.S. & Turban, S. (2018). The impact of the open workspace on human collaboration. *Philosophical Transactions of the Royal Society B* 373(1753).
- BIS (2025). Residential Property Price Statistics. Bank for International Settlements, Basel.
- EpochAI (2026). Trends in Machine Learning: Compute, Capability, and Cost Trajectories. Epoch AI Research.
- Eurostat (2026). HICP: Construction sub-index CP0421. European Commission, Luxembourg.
- George, H. (1879). *Progress and Poverty*. D. Appleton, New York.
- Glaeser, E.L. (2011). *Triumph of the City*. Penguin Press, New York.
- Glaeser, E.L. & Gyourko, J. (2018). The Economic Implications of Housing Supply. *Journal of Economic Perspectives* 32(1), 3–30.
- Google DeepMind (2021). Highly accurate protein structure prediction with AlphaFold. *Nature* 596, 583–589.
- IEA (2024). Solar PV Global Supply Chains. International Energy Agency, Paris.
- ILO (2024). ILOSTAT: Construction Sector Wages. International Labour Organization, Geneva.
- Jackson, M.D. et al. (2017). Unlocking the secrets of Al-tobermorite in Roman seawater concrete. *American Mineralogist* 102, 1435–1450.
- Jordà, Ò., Schularick, M. & Taylor, A.M. (2019). The Rate of Return on Everything, 1870–2015. *Quarterly Journal of Economics* 134(3), 1225–1298.
- Kahneman, D. (2011). *Thinking, Fast and Slow*. Farrar, Straus and Giroux.
- McKinsey Global Institute (2017). *Reinventing Construction: A Route to Higher Productivity*. McKinsey.
- McKinsey Global Institute (2024). *AI in Construction: Current State and Deployment Trajectories*. McKinsey.
- Melo de Magalhães, G. (2026a). *The Architecture of Freedom Intelligence*. Zenodo. <https://doi.org/10.5281/zenodo.18636095>
- Melo de Magalhães, G. (2026b). *Spatial Freedom Fields: A Rigorous Computational Framework for AFI*. Zenodo. <https://doi.org/10.5281/zenodo.18845574>
- Melo, G. (2026c). *A Structural Law of Swarm Intelligence*. SSRN. <https://ssrn.com/abstract=6304936>
- Nordhaus, W.D. (2021). Are We Approaching an Economic Singularity? *American Economic Journal: Macroeconomics* 13(1), 218–259.
- OECD (2024). *Affordable Housing Database*. OECD Publishing, Paris.
- OpenAI (2024). *GPT-4o Technical Report*. OpenAI Research.
- Anthropic (2024). *Claude 3.5 Sonnet Model Card*. Anthropic Research.
- Google (2024). *Gemini 1.5: Unlocking multimodal understanding across millions of tokens of context*. arXiv:2403.05530.
- Popper, K. (1959). *The Logic of Scientific Discovery*. Hutchinson, London.
- Rankin, K.H., Serrenho, A.C. & Saxe, S. (2026). The climate limits of construction in over 1,000 cities. *Nature Cities* 3(1). <https://doi.org/10.1038/s44284-025-00192-7>
- Ricardo, D. (1817). *On the Principles of Political Economy and Taxation*. John Murray, London.
- Sevtsuk, A. et al. (2026). Spatial distribution of foot traffic. *Nature Cities* 3(2).
- Taleb, N.N. (2007). *The Black Swan*. Random House, New York.
- Taleb, N.N. (2012). *Antifragile*. Random House, New York.
- Taleb, N.N. (2018). *Skin in the Game*. Random House, New York.
- Tetlock, P. & Gardner, D. (2015). *Superforecasting*. Crown Publishers.
- World Bank (2024). *Doing Business 2024: Dealing with Construction Permits*. World Bank Group.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.