Statistical Life Expectancy of a Biologically Non-Senescent Human

A scenario-based analysis of residual extrinsic mortality under the abolition of ageing (longevity escape velocity)

Theoretical / counterfactual study · constant-hazard (Makeham) survival model · empirical inputs: CDC/NCHS, Eurostat, WHO

Abstract

We treat as a formal thought experiment the counterfactual in which biological senescence is abolished — the asymptotic endpoint of longevity escape velocity (LEV) — and ask how long a person would then live given that death from external causes (accidents, violence, war, catastrophe) is not eliminated. If the age-dependent Gompertz term of mortality is removed, only the age-invariant Makeham term remains; lifetime is then exponentially distributed and mean life expectancy is the reciprocal of the residual extrinsic hazard. Using contemporary injury-mortality data we obtain a baseline mean of order 1,000–2,000 years (median ≈ 700–1,500 years). We extend the analysis with (i) the exact moments and quantiles of the distribution, (ii) a Monte Carlo validation, (iii) a non-stationary model in which the extrinsic hazard itself declines over time, yielding a strictly positive probability of never dying from extrinsic causes, and (iv) an irreducible global-catastrophic hazard floor that bounds the optimistic tail. Across scenarios spanning civilisational collapse to a safety-saturated future, life expectancy ranges over nearly five orders of magnitude, from ~14 to ~100,000 years, with the true long-run ceiling set not by everyday accidents but by rare catastrophic risk.

Keywords: longevity escape velocity; extrinsic (background) mortality; Gompertz–Makeham law; constant-hazard survival; exponential lifetime; global catastrophic risk.

1. Introduction

The concept of longevity escape velocity (LEV), introduced by Gobel and formalised by de Grey [1], describes a regime in which rejuvenation therapy extends remaining life expectancy faster than time elapses, so that age-related mortality is indefinitely outrun. This study does not assess whether LEV is attainable; we take its asymptotic endpoint — the complete abolition of senescence — as a given premise and analyse a strictly downstream question of actuarial arithmetic: **if people no longer aged, how long would they in fact live?** The exercise is counterfactual and not presently realisable, but it is well posed and admits rigorous treatment.

Human mortality is well described by the Gompertz–Makeham law, $\mu(x) = A + B \cdot e^{\theta x}$, where the exponential term captures senescence and the constant term A — the Makeham term — captures age-independent “background” or **extrinsic** mortality. Abolishing ageing corresponds to $B \to 0$ (or $\theta \to 0$), leaving a hazard that is constant in age: $\mu(x) = A \equiv \lambda$. This single substitution is the entire formal content of the problem; everything below follows from it.

2. The constant-hazard model

Under a hazard λ that is constant in both age and time, the time of death T is exponentially distributed. Writing r for the number of deaths per 100,000 persons per year, $\lambda = r/100{,}000$. The core relations are:

$$S(t) = e^{-\lambda t} \,,\ f(t) = \lambda e^{-\lambda t} \,,\ E[T] = 1/\lambda \,,\ SD[T] = 1/\lambda \,,\ \text{median} = \ln 2/\lambda \approx 0.693/\lambda$$

Two features deserve emphasis. First, the distribution is exponential, not bell-shaped: the modal age at death is zero and there is **no characteristic lifespan**. Second, the standard deviation equals the mean (coefficient of variation = 1), so outcomes are enormously dispersed. The quantile function $t_p = -\ln(1-p)/\lambda$ gives the age by which a fraction p has died; equivalently, survivorship falls to fixed fractions at fixed multiples of the mean E:

Survivors remaining	Reached at age	In multiples of mean E	EU baseline (E≈2,130 yr)
50% (median)	ln2 / λ	0.693 · E	~1,480 yr

Survivors remaining	Reached at age	In multiples of mean E	EU baseline (E≈2,130 yr)
10%	ln10 / λ	2.303 · E	~4,900 yr
1%	ln100 / λ	4.605 · E	~9,810 yr
0.1%	ln1000 / λ	6.908 · E	~14,710 yr

Table 1. Quantiles of the exponential lifetime. The heavy right tail means a small minority live several times the mean.

3. Empirical baseline scenarios (present-day rates)

We first insert observed extrinsic-mortality rates. The US age-adjusted all-injury death rate was 85.3 per 100,000 in 2023 (CDC/NCHS), implying a mean of ≈1,170 years. Eurostat standardised rates for the EU (2022) — accidents 35.6, intentional self-harm 10.6, assault 0.7 per 100,000 — sum to 46.9, giving ≈2,130 years. These reproduce the canonical order-of-magnitude estimate of ~1,000 years frequently quoted in the life-extension literature [1,7,8].

Scenario	r (/100k/yr)	Mean (yr)	Median (yr)	P(survive 1,000 yr)
US — all injury (2023)	85.3	~1,170	~810	43%
World — mean (WHO injuries)	~57	~1,750	~1,220	57%
EU — accidents + violence + self-harm	46.9	~2,130	~1,480	63%
US — “prudent” (excl. suicide + overdose)	~39	~2,560	~1,780	68%
Safest observed human cohort (~age 10)	~10	~10,000	~6,900	90%

Table 2. Life expectancy under unchanged present-day extrinsic mortality.

A caveat already appears here: part of this mortality reflects choice rather than chance (suicide, overdose). An agent who wishes to live avoids these, shifting from ~1,170 to ~2,560 years. Moreover, elderly falls — today a leading injury category — stem largely from frailty and would collapse absent senescence, so the true “extrinsic-only” figure is somewhat higher than the naive arithmetic.

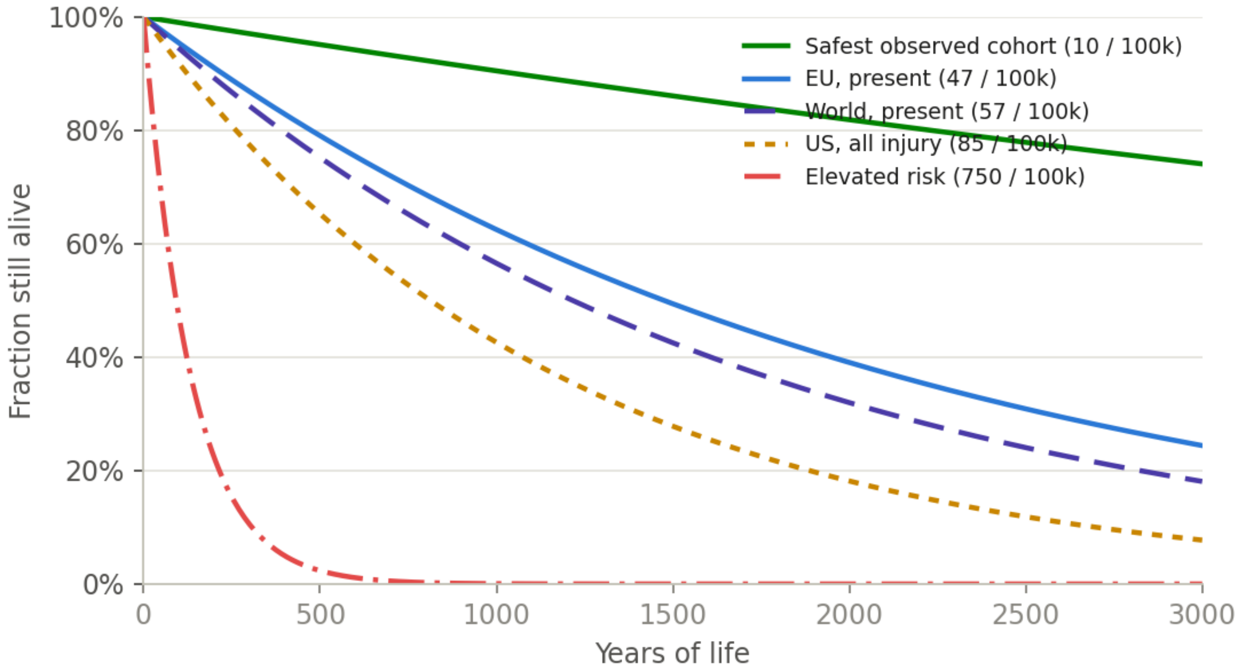

Figure 1. Survival curves $S(t)=e^{-r \cdot t/100,000}$. Even at present rates, half of the non-senescent population dies within ~1,000–1,500 years.

4. Prospective scenarios (declining risk)

Because E ∝ 1/r, a 50% cut in the extrinsic rate doubles lifespan and a 75% cut quadruples it. History supports large reductions: the US road-death rate per mile fell ~93% since 1923, while aviation approaches a floor (~0.006 deaths/100k/yr in the US, ~10,000× below total injury mortality) [8].

Scenario	Mechanism	r	Mean (yr)
Moderate future (−75%)	autonomous transport, robots in hazardous work, better trauma care	~12	~8,300
Advanced	near-elimination of accidents, absence of war, biometric monitoring	~4	~25,000
Safety utopia	theoretical ceiling of safety engineering; only rare freak accidents remain	~1	~100,000

Table 3. Prospective reductions. The top value is a theoretical ceiling of accident engineering, itself bounded by catastrophic risk (§9).

Notably, and against intuition, **war is statistically minor**. In tribal societies 10–20% of people died violently in raids and warfare; global war-death rates peaked near 300 per 100,000/yr in WWII but stand near 1 per 100,000/yr today [6,8]. Even large further reductions in war risk barely move life expectancy, because the baseline is already negligible against everyday accidents.

5. Adverse and dystopian scenarios

The following are order-of-magnitude estimates (flagged as such), anchored in occupational-fatality and historical-violence data rather than a single source. For calibration, the deadliest present-day occupations (deep-sea fishing, logging) run ~100–130 deaths/100k/yr, so merely holding a hazardous job already caps life at ~800–1,000 years irrespective of ageing.

Scenario	Annual risk	r	Mean (yr)	Median (yr)
Elevated risk (crime resurgence, chronic unrest)	0.75%	750	~130	~90
Active war zone (worst modern conflicts)	1.5%	1,500	~67	~46
Partial collapse / tribal-level violence	3%	3,000	~33	~23
Total civilisational collapse (no medicine, exposure)	7%	7,000	~14	~10

Table 4. High-mortality regimes. Values of r are the author's estimates from violence and injury data.

The implication is stark: in a Hobbesian regime, biological non-senescence buys almost nothing — the immortal in a collapsed civilisation lives about as long as a Palaeolithic human (tens of years), because others kill him long before "immortality" can express itself.

6. Frontier and extraterrestrial scenarios

Human spaceflight to date offers a hard anchor: roughly 3–4% of all people who have flown to space died in the attempt. Early off-world settlement — micrometeoroids, decompression, radiation, life-support failure, absence of redundant infrastructure — is plausibly the deadliest environment considered here.

Scenario	Annual risk (est.)	r	Mean (yr)
Mature, engineered habitat	0.3%	300	~330
Early colony (pioneer phase)	3%	3,000	~33
Extreme frontier work (asteroid mining, etc.)	5%	5,000	~20

Table 5. Exploration and off-world scenarios.

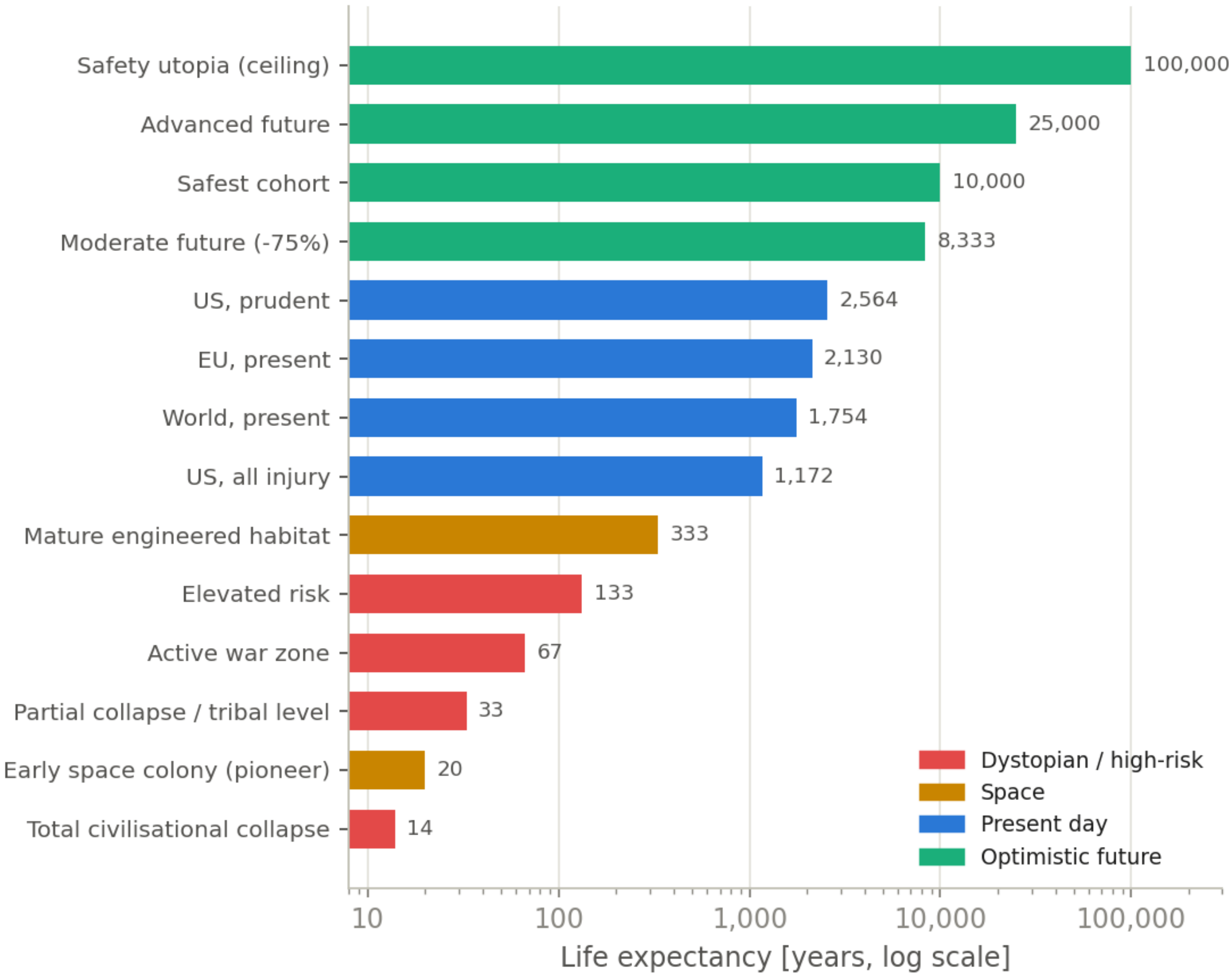

Figure 2. Life expectancy across all scenarios on a logarithmic axis (~14 to ~100,000 years).

7. Monte Carlo validation

To confirm the analytic result and visualise the full distribution, we drew N = 300,000 independent samples from an exponential distribution with the EU-baseline hazard ($\lambda = 4.7\times10^{-4}\ \mathrm{yr}^{-1}$). The simulated moments reproduce the closed-form values to within sampling error: mean 2,124 yr (analytic 2,128), median 1,469 yr (1,478), 90th percentile 4,889 yr (4,901), 99th percentile 9,774 yr (9,800). The exercise makes the heavy tail concrete — roughly one settler in a hundred, in an otherwise ordinary present-day risk environment, would exceed 9,800 years.

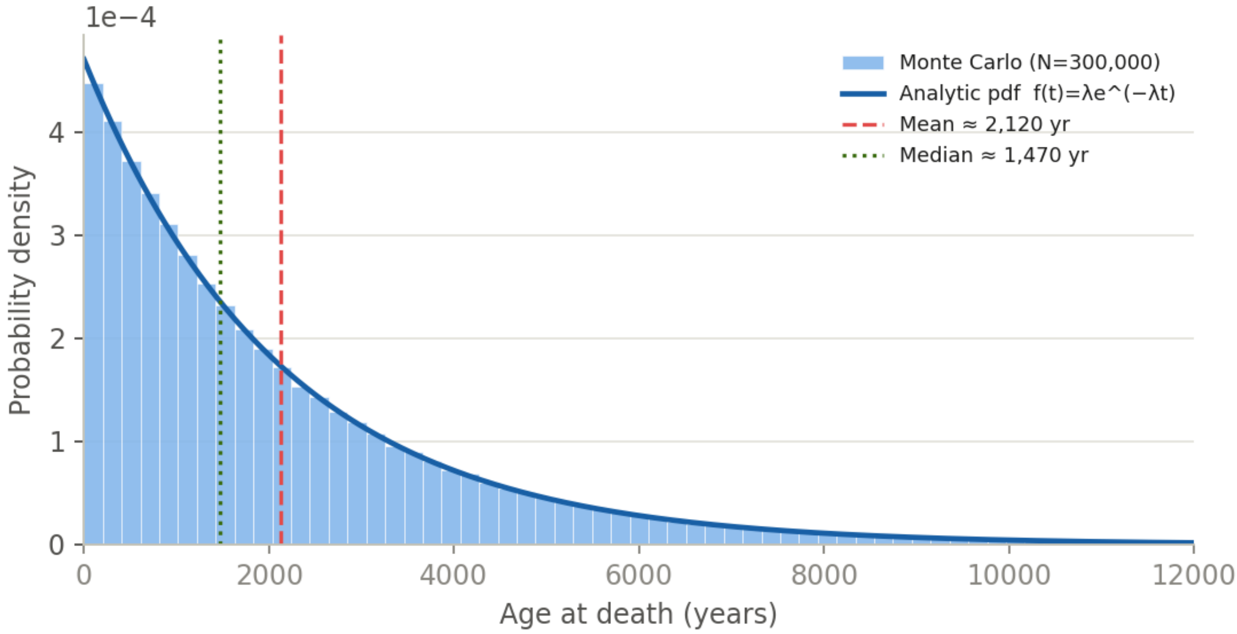

Figure 3. Monte Carlo distribution of age at death (EU baseline) against the analytic exponential density.

8. Non-stationary hazard and the extrinsic escape probability

The constant-hazard model assumes safety is frozen. But if the extrinsic rate itself declines — as it has historically — the picture changes qualitatively. Let the hazard decay exponentially, $\lambda(t) = \lambda_0 e^{-gt}$, where g is the fractional annual rate of safety improvement. The cumulative hazard is finite in the limit:

$$H(t) = (\lambda_0/g)(1 - e^{-gt}) \ , \ S(\infty) = \exp(-\lambda_0/g) > 0$$

Thus a **strictly positive fraction never dies of extrinsic causes at all** — an “extrinsic escape probability” $p_{esc} = \exp(-\lambda_0/g)$. This is the direct actuarial analogue of LEV, applied to the Makeham term rather than the Gompertz term. Its value depends only on the ratio λ_0/g:

Safety-improvement rate g	λ_0 / g	Escape probability p_esc = exp(−λ_0/g)
0 (static)	∞	0%
0.1% / yr	0.470	62.5%
0.2% / yr	0.235	79.1%
0.5% / yr	0.094	91.0%
1% / yr	0.047	95.4%
2% / yr	0.0235	97.7%

Table 6. Fraction of the EU-baseline population escaping extrinsic mortality entirely, as a function of the safety-improvement rate.

These g-values are historically plausible: the ~93% century-scale fall in the US road-death rate corresponds to g ≈ 2.5%/yr within that single hazard category (aggregate g across all causes is smaller). The escape here is relative to accidents only; it does not confer true permanence, which is removed by the catastrophic floor of §9.

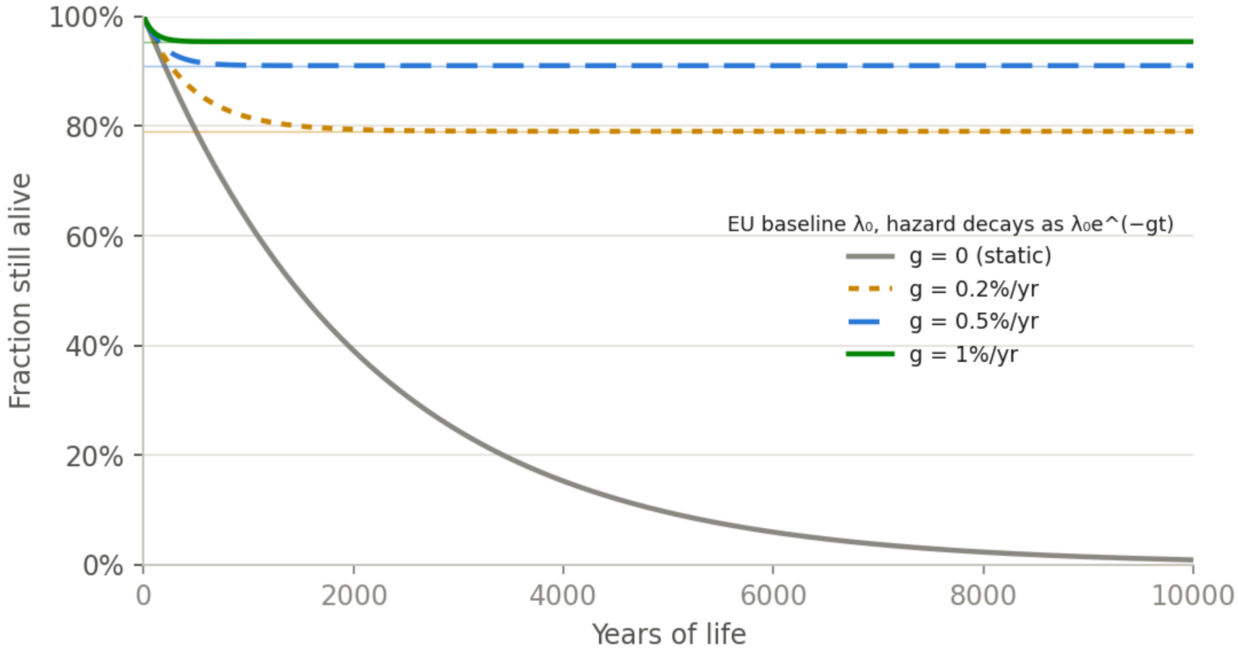

Figure 4. Survival under a decaying hazard. Unlike the static case (which tends to zero), each dynamic curve plateaus at a positive asymptote S(∞).

9. Catastrophic hazard floor and the true ceiling

No amount of personal caution removes exposure to events that kill everyone at once — broad-spectrum pandemics, asteroid or comet impact, supervolcanism, and anthropogenic catastrophe. Model these as an irreducible constant hazard λ_c added in parallel: $\lambda_{total} = \lambda_{personal} + \lambda_c$. As personal risk is driven toward zero, life expectancy is capped at $E_{max} = 1/\lambda_c$.

Irreducible catastrophic hazard λ_c	**Ceiling E_max = 1/λ_c**
10^{-3} / yr	~1,000 yr
10^{-4} / yr	~10,000 yr
10^{-5} / yr	~100,000 yr
10^{-6} / yr	~1,000,000 yr

Table 7. The catastrophic floor sets the ceiling on the optimistic tail, independent of everyday accident rates.

Calibration is highly uncertain and regime-dependent. Ord [5] estimates the probability of an existential catastrophe within the present century at roughly one in six; if that elevated, largely anthropogenic rate were permanent it would imply $\lambda_c \approx 1.8\times10^{-3}$/yr and a ceiling near 550 years — a striking result, since it would render most gains from defeating ageing moot. Ord argues, however, that this is a transient “Precipice”, and bounds the long-run **natural** background rate below ~1 in 10,000 per century ($\lambda_c < 10^{-6}$/yr, ceiling > 10^6 years). The binding constraint on human longevity, in this framework, is therefore not the car or the fall but the trajectory of civilisational risk.

10. Synthesis

Reduced to headline figures: at present extrinsic-mortality rates a biologically non-senescent human would live on average ~1,000–2,000 years, with a median of ~700–1,500 years; because lifetime is exponential, ~10% would exceed ~2.3× the mean and ~1% would exceed ~4.6× the mean. If safety continues to improve at even a fraction of a percent per year, a majority may escape extrinsic mortality entirely (§8). But the optimistic tail is capped by catastrophic risk (§9) somewhere between ~10^3 and >10^6 years, depending on whether anthropogenic peril subsides. In no scenario is life truly unbounded: abolishing ageing converts a near-certain death at ~80 into a probabilistic death spread over centuries to millennia.

11. Limitations and methodological caveats

Fat tails. The parallel-hazard treatment of catastrophic risk (§9) is deliberately crude; real catastrophic hazards are correlated, non-stationary, and possibly regime-switching, and they dominate outcomes over multi-millennial horizons.

Endogenous λ. The hazard is not exogenous: a person with millennia at stake would rationally minimise risk, arguing for the lower r values — yet risk compensation (the Peltzman effect) and extreme, possibly paralysing risk-aversion pull in opposite directions. The behavioural equilibrium is unknown.

Voluntary termination. As all involuntary causes shrink, self-chosen death necessarily rises in relative share and could become the leading cause; it is a decision parameter set by culture and philosophy, not an accident rate, and is excluded from the model.

Age structure of extrinsic hazard. Real background mortality is not perfectly flat: it peaks in late adolescence/early adulthood (accidents, violence) and — absent the frailty component — would otherwise be nearly age-invariant. The constant-hazard assumption is thus a first-order approximation.

Period vs cohort. All inputs are synthetic-cohort period rates; a real long-lived cohort would experience secular change (the subject of §8), so static figures should be read as snapshots, not forecasts.

12. Data sources and references

[1] de Grey, A. D. N. J. (2004). Escape Velocity: Why the Prospect of Extreme Human Life Extension Matters Now. PLoS Biology 2(6): e187.

[2] Centers for Disease Control and Prevention / NCHS. Injury mortality, United States, 2023 (age-adjusted all-injury death rate 85.3 per 100,000).

[3] Eurostat (2022). Standardised death rates by cause: accidents, intentional self-harm, assault (EU).

[4] World Health Organization. Global Health Estimates: mortality from injuries.

[5] Ord, T. (2020). The Precipice: Existential Risk and the Future of Humanity. Hachette.

[6] Pinker, S. (2011). The Better Angels of Our Nature: Why Violence Has Declined. Viking.

[7] Friedel, F. (2017). Estimate of ~1,000-year accident-limited lifespan for a non-ageing human.

[8] More, M. (2026). How Long Might We Live if Aging Were Eliminated? The Biostasis Standard (decomposition of non-longevity mortality; synthesis of the above sources).

Note. Scenario values for the adverse (§5) and frontier (§6) cases are the author's order-of-magnitude estimates, anchored in occupational-fatality statistics, historical-violence data, and the human-spaceflight record; they illustrate the model's sensitivity and are not predictions. All figures are rounded.