

BEYOND LIFESPAN: HUMAN SUSTAINABILITY AS AN INTEGRATIVE PARADIGM FOR WOMEN'S EMOTIONAL LONGEVITY AND HEALTHY AGEING

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ABSTRACT

Longevity science has progressed from preventing premature death to delaying biological ageing and extending health span. Despite major advances in geroscience, genomics, precision medicine, regenerative therapies and preventive care, contemporary models remain weighted toward biological mechanisms and clinical biomarkers. They insufficiently explain how emotional resilience, cognitive adaptability, social connectedness, caregiving, occupational participation, financial security, environmental conditions and purpose shape ageing trajectories, particularly among women. This conceptual review proposes Human Sustainability as an integrative life-course paradigm for healthy longevity. Human Sustainability is defined as the lifelong capacity to preserve, regenerate and adapt biological, emotional, cognitive, relational, occupational, financial, environmental and existential resources in ways that support meaningful and equitable ageing. Within this paradigm, Emotional Longevity is introduced as the sustained capacity for emotional regulation, psychological flexibility, recovery, connection and purpose across cumulative life transitions. Women's Sustainability is presented as the gender-responsive application of Human Sustainability, recognising the interaction of reproductive transitions, caregiving, employment, social expectations and structural inequalities across the female life course. The paper develops the Human Sustainability Systems Model (HSSM), which conceptualises longevity as an emergent outcome of interacting adaptive systems rather than isolated biological processes. The framework complements, rather than replaces, Healthy Ageing, Geroscience, Precision Medicine, One Health, Planetary Health and the Social Determinants of Health. A research agenda is proposed for construct refinement, scale development, longitudinal validation, intervention testing and implementation. The paper concludes that additional years of life should be evaluated not only through survival and disease-free time, but also through resilience, autonomy, connection, participation, dignity and purpose.

KEY TERMS: Human sustainability; emotional longevity; women's sustainability; healthy ageing; life-course approach; resilience; geroscience; systems thinking.

I. INTRODUCTION

Global longevity is increasing. The United Nations estimated global life expectancy at birth at 73.3 years in 2024, representing substantial improvement over recent decades (United Nations, 2024). Longer lives create opportunities for participation, learning, contribution and intergenerational exchange, but they also expose a central policy and clinical challenge: additional years are not automatically healthy, autonomous or meaningful.

WHO defines healthy ageing as the process of developing and maintaining the functional ability that enables well-being in older age (WHO, 2020a). This definition appropriately extends attention beyond disease status to what people are able to be and do. Nevertheless, the operationalisation of longevity science remains strongly influenced by biomedical indicators such as metabolic health, cardiovascular fitness, inflammation, genomic stability, cellular senescence and biological age.

These measures are indispensable, but they do not fully capture why people with comparable biological profiles may differ markedly in coping, social participation, functional independence and quality of life. Ageing is simultaneously

biological, emotional, cognitive, relational, occupational, financial, environmental and existential. Chronic stress, social isolation, insecure work, caregiving burden, financial strain and loss of purpose can affect behaviour, neuroendocrine regulation, inflammation, sleep and healthcare use, while supportive relationships and meaningful participation can protect health across the life course (McEwen, 1998; Holt-Lunstad et al., 2010; Slavich & Irwin, 2014).

The need for an expanded framework is especially visible in women's ageing. Women commonly live longer than men but may spend more years with disability, chronic illness, depression, caregiving responsibilities and financial vulnerability. The female health-survival paradox illustrates why longevity cannot be evaluated through life expectancy alone (Oksuzyan et al., 2008). Women's trajectories are shaped by reproductive transitions, gendered labour, unpaid care, workplace conditions, social expectations and unequal access to resources.

A. Problem Statement

Existing longevity frameworks have significantly advanced the understanding of biological ageing, functional capacity and disease prevention. However, the determinants of sustained emotional adaptation, social participation, occupational meaning, financial resilience and existential well-being remain fragmented across disciplines. Healthy Ageing, Geroscience, Precision Medicine, the Biopsychosocial Model, Social Determinants of Health, One Health and Planetary Health each contribute important insights, but none fully integrates the eight domains proposed in this paper within a unified life-course model of sustainable longevity.

The conceptual problem is therefore not an absence of relevant evidence, but the absence of an organising framework that explains how multiple adaptive systems interact across decades. Without such integration, clinical assessment may focus on biomarkers while overlooking caregiving burden or loneliness; workplace programmes may address stress without financial insecurity; and healthy-ageing policy may promote activity without examining access, safety or purpose.

B. Aim, Objectives and Research Questions

The aim of this paper is to develop Human Sustainability as an integrative conceptual paradigm for healthy longevity and to specify its application to emotional ageing and women's life-course health.

- i. Trace the evolution of longevity science from survival and disease control toward multidimensional healthy ageing.
- ii. Define Human Sustainability and distinguish it from existing biomedical and psychosocial frameworks.
- iii. Develop Emotional Longevity as a life-course construct relevant to healthy ageing.
- iv. Develop Women's Sustainability as a gender-responsive life-course application of Human Sustainability.
- v. Present the Human Sustainability Systems Model and propose research, clinical and policy applications.

The paper addresses three questions: What is missing from predominantly biomedical models of longevity? How can emotional and gender-responsive determinants be integrated without diluting biological science? Which research steps are required to transform the proposed concepts into valid and useful measures?

II. MATERIALS, METHODS AND CONCEPTUAL DEVELOPMENT

A. Review Design

A critical integrative review was used to combine evidence and theory from geroscience, neuroscience, psychology, behavioural medicine, public health, women's health, social epidemiology, occupational health and systems science. The purpose was conceptual synthesis rather than estimation of a pooled effect.

B. Evidence Base

The paper draws on foundational and contemporary literature concerning the hallmarks of ageing, healthy ageing, life-course epidemiology, resilience, emotion regulation, social connection, cognitive reserve, stress biology, women's health, social determinants and measurement science. Recent evidence on population ageing, multidimensional resilience and social connection was included to update the conceptual foundation.

C. Conceptual Synthesis Procedure

Conceptual development proceeded through five stages: identification of limitations in existing longevity models; extraction of recurring determinants across disciplines; consolidation of determinants into eight domains; specification of hypothesised feedback pathways; and differentiation of Human Sustainability, Emotional Longevity and Women's Sustainability from related constructs.

D. Criteria for Conceptual Utility

The proposed framework was evaluated against five criteria: conceptual clarity, distinctiveness, compatibility with established science, potential measurability and practical relevance. Because the framework is conceptual, claims are presented as propositions requiring empirical testing rather than as established causal conclusions.

E. Limitations of the Method

The review is not a systematic review and does not exhaust all literature relevant to ageing. The eight-domain structure reflects interdisciplinary synthesis and may require revision through expert consensus, cross-cultural research and empirical modelling. The paper therefore provides a testable framework rather than a validated instrument.

III. EVOLUTION OF LONGEVITY SCIENCE

A. From Survival to Prevention

The first major gains in life expectancy followed sanitation, vaccination, antibiotics, nutrition and maternal-child health improvements. Success was primarily measured through reduced mortality. As chronic diseases became more prominent, preventive medicine shifted attention toward modifiable risk factors, screening and early intervention.

B. Healthy Ageing and Functional Ability

Healthy-ageing frameworks broadened the goal from survival to functional ability, intrinsic capacity and participation. WHO's approach recognises that well-being depends on the interaction between intrinsic capacity and the environment, creating a strong foundation for person-centred ageing policy (Beard et al., 2016; WHO, 2020a).

C. Geroscience, Precision Medicine and Longevity Medicine

Geroscience links fundamental ageing processes to multiple chronic diseases. The hallmarks of ageing framework identifies interacting biological processes including genomic instability, telomere attrition, epigenetic alterations, loss of proteostasis, impaired autophagy, deregulated nutrient sensing, mitochondrial dysfunction, cellular senescence, stem-cell exhaustion, altered intercellular communication, chronic inflammation and dysbiosis (López-Otín et al., 2023). Precision medicine and digital health further personalise risk assessment and intervention.

D. The Remaining Integrative Gap

Biomedical innovation can improve health span, but the lived experience of longer life is shaped by conditions not reducible to biomarkers. Resilience in later life is multidimensional, and social isolation is associated with lower likelihood of healthy ageing across sexes (Jacob et al., 2025; Miao et al., 2025). The emerging challenge is therefore to connect biological science with the adaptive capacities that sustain functioning and meaning.

IV. HUMAN SUSTAINABILITY

A. Definition

Human Sustainability is defined as the lifelong capacity of individuals, communities and societies to preserve, regenerate and adapt biological health, emotional resilience, cognitive vitality, relational connectedness, occupational participation, financial security, environmental support and existential purpose in ways that enable healthy, equitable and meaningful longevity.

The term sustainability is used in a regenerative and adaptive sense. It does not imply that individuals are solely responsible for maintaining well-being. Capacity is produced through the interaction of personal resources, relationships, institutions, labour markets, healthcare, public policy and physical environments.

B. Eight Domains

Table 1. Domains and provisional indicators of Human Sustainability

Domain	Core components	Illustrative indicators	Potential assessment	Illustrative intervention
Biological	Physiological reserve, mobility, sleep, metabolic and immune function	Multimorbidity, intrinsic capacity, frailty and biomarkers	Clinical assessment and validated functional measures	Prevention, rehabilitation, nutrition and physical activity
Emotional	Regulation, flexibility, coping, recovery and renewal	Distress, affect balance, resilience and emotional adaptability	Patient-reported measures and longitudinal assessment	Psychological interventions, mindfulness and trauma-informed care
Cognitive	Memory, attention, executive function, learning and creativity	Cognitive performance and reserve	Neuropsychological testing and functional tasks	Lifelong learning, cognitive stimulation and risk-factor management
Relational	Social support, belonging, reciprocity and participation	Loneliness, network quality and social engagement	Network and loneliness measures	Community connection, peer support and intergenerational programmes
Occupational	Meaningful work, autonomy, contribution and work-life sustainability	Burnout, engagement, participation and transition quality	Workplace and occupational-health measures	Flexible work, redesign, retraining and retirement planning
Financial	Income security, healthcare affordability and resilience to shocks	Material hardship, debt stress and financial well-being	Financial-well-being and access measures	Social protection, financial literacy and equitable pensions
Environmental	Safe housing, mobility, green space, climate resilience and care access	Exposure, accessibility and neighbourhood quality	Environmental and age-friendly community audits	Universal design, transport, climate adaptation and healthy urban planning
Existential	Purpose, values, identity, spirituality, creativity and meaning	Purpose in life, coherence and generativity	Purpose and meaning measures	Meaning-centred care, volunteering and creative participation

C. Systems Properties

Human Sustainability is proposed as a dynamic system rather than a checklist. Its domains are interdependent, recursive and context-sensitive. Financial insecurity may increase stress and reduce healthcare access; emotional distress may disrupt sleep and social participation; meaningful work may strengthen identity and cognitive engagement; and accessible environments may support mobility and connection.

The framework also incorporates accumulation and timing. Early-life disadvantage may shape education, occupation, health behaviours and biological risk decades later, while later-life interventions may still improve adaptation and participation. This is consistent with life-course epidemiology, which emphasises trajectories, transitions and cumulative exposure (Ben-Shlomo & Kuh, 2002).

D. Relationship to Existing Frameworks

Table 2. Relationship between Human Sustainability and established frameworks

Framework	Primary contribution	Relative limitation for this purpose	How Human Sustainability extends it
Healthy Ageing	Functional ability, intrinsic capacity and enabling environments	Less explicit attention to occupational, financial and existential systems	Adds a broader life-course systems architecture
Geroscience	Biological mechanisms linking ageing to chronic disease	Predominantly molecular and physiological	Links biological ageing to psychosocial and structural feedback
Precision Medicine	Individualised prevention and treatment using biological and digital data	Risk of biological reductionism and unequal access	Adds context, equity and multidomain assessment
Biopsychosocial Model	Integration of biological, psychological and social dimensions	Broad but not specifically structured around longevity or eight domains	Provides a longevity-specific, measurable systems model
Social Determinants of Health	Structural conditions shaping health inequity	May not specify emotional, cognitive and existential adaptation in detail	Connects structural conditions with adaptive capacities
One Health and Planetary Health	Interdependence of human, animal and environmental health	Limited focus on individual emotional, occupational and existential systems	Connects environmental sustainability with whole-person longevity
Successful Ageing	Function, engagement and low disease burden	Potentially normative and exclusionary for people living with disability	Emphasises adaptation, dignity and flourishing with or without illness

V. EMOTIONAL LONGEVITY

A. Definition and Rationale

Emotional Longevity is defined as the lifelong capacity to preserve, regenerate and adapt emotional functioning in ways that sustain psychological flexibility, emotional regulation, recovery, compassion, meaningful relationships and purpose across cumulative ageing and life adversity.

The construct is longitudinal. It does not describe permanent happiness or the absence of distress. It recognises that emotional functioning may be disrupted by illness, loss, caregiving, occupational change, menopause, retirement and bereavement, yet can recover, reorganise and deepen.

B. Distinction From Related Constructs

Resilience commonly concerns adaptation after adversity; emotional intelligence concerns awareness and management of emotion; psychological well-being concerns current functioning; and emotion regulation concerns processes used to influence emotional experience. Emotional Longevity integrates these traditions while focusing on their preservation and renewal across decades.

C. Proposed Dimensions

- i. Emotional awareness and literacy.
- ii. Regulation of affect without chronic suppression or dysregulation.
- iii. Psychological flexibility and context-sensitive coping.
- iv. Recovery and reorganisation after adversity.
- v. Self-compassion and reduced self-stigmatisation.
- vi. Hope, realistic optimism and future orientation.
- vii. Relational connectedness, empathy and reciprocal support.
- viii. Meaning, purpose and continuity of identity.
- ix. Capacity for contribution, creativity and emotional renewal.

D. Hypothesised Mechanisms

Emotional Longevity may influence healthy ageing through several pathways. Adaptive regulation can reduce prolonged stress activation; flexible coping may support treatment adherence and health behaviour; social connection can buffer adversity; and purpose may support motivation and participation. These pathways plausibly interact with neuroendocrine, immune, cardiovascular and cognitive systems, but the independent predictive value of the construct requires empirical testing.

E. Measurement Development

A future Emotional Longevity Scale should be developed through qualitative research, expert consensus and psychometric validation. Item generation should include diverse cultures and life stages, followed by content validity, factor analysis, reliability testing, measurement invariance and prospective validation against mental health, functional ability, health behaviours and quality of life (DeVellis, 2017; Mookink et al., 2018).

VI. WOMEN'S SUSTAINABILITY

A. Definition

Women's Sustainability is defined as the lifelong capacity of women to preserve, regenerate and adapt biological health, emotional resilience, cognitive vitality, relational connectedness, occupational participation, financial security, environmental support and existential purpose across developmental, reproductive and social transitions.

B. A Gender-Responsive Life-Course Perspective

Women's Sustainability applies the Human Sustainability framework to gendered experiences without reducing women's health to reproductive biology. Puberty, pregnancy, postpartum recovery, perimenopause, menopause and later ageing interact with education, employment, caregiving, violence exposure, social expectations, healthcare access and financial security.

The framework should also avoid treating women as a homogeneous group. Ageing trajectories vary by socioeconomic position, disability, race or ethnicity, migration, family structure, occupation, geography and culture. Intersectional analysis is therefore essential to prevent a universalised model based on privileged populations.

C. The Female Health-Survival Paradox

Women's longer average survival coexists with higher disability and morbidity in many settings. Potential contributors include disease patterns, occupational and caregiving exposure, healthcare access, social disadvantage and differences in reporting and diagnosis. A sustainability framework shifts attention from lifespan alone to the quality, autonomy and equity of additional years.

D. Life-Course Transitions and Accumulation

Table 3. Women's Sustainability across the life course

Life stage	Key transitions	Potential sustainability risks	Protective resources	Priority response
Childhood and adolescence	Growth, education, identity and reproductive maturation	Violence, malnutrition, school exclusion and mental distress	Safe family, education, health services and belonging	Protection, nutrition, mental-health support and educational continuity
Early adulthood	Higher education, work, relationships and possible parenthood	Employment insecurity, reproductive-health barriers and unequal care burden	Skills, autonomy, supportive relationships and healthcare	Reproductive choice, safe work, childcare and financial capability
Midlife	Career progression, caregiving and menopausal transition	Burnout, chronic disease, sleep disruption and financial strain	Flexible work, social support, preventive care and agency	Integrated menopause care, caregiver support and workplace flexibility
Later adulthood	Retirement, bereavement, chronic illness and changing roles	Isolation, income loss, disability and ageism	Pension security, age-friendly environments and meaningful participation	Integrated care, social connection, mobility and purpose
Advanced age	Increasing dependency or adaptation to frailty	Care gaps, exclusion and loss of autonomy	Person-centred care, trusted relationships and accessible environments	Dignity, supported decision-making and continuity of identity

E. Clinical and Policy Implications

Gender-responsive healthy-ageing assessment should include emotional well-being, caregiving, work, financial security, violence exposure, social support and purpose alongside biological and reproductive health. Policy implications include equitable preventive care, caregiver support, workplace flexibility, pension protection, lifelong education, safe environments and age-friendly services.

VII. HUMAN SUSTAINABILITY SYSTEMS MODEL

A. Model Architecture

The Human Sustainability Systems Model (HSSM) is the conceptual architecture connecting the eight domains. It assumes that healthy longevity is an emergent property of interactions among systems rather than the result of a single determinant. Each domain contains resources and vulnerabilities, and change in one domain can produce reinforcing or balancing effects elsewhere.

B. Feedback Loops

A reinforcing vulnerability loop may begin with occupational stress, which disrupts sleep, increases emotional distress, weakens relationships and reduces physical activity. A protective loop may begin with meaningful social participation, which strengthens purpose, cognitive engagement, emotional regulation and healthy behaviour. These loops accumulate across time and are shaped by structural opportunity.

C. Multilevel Context

HSSM is explicitly multilevel. Individual capacities are embedded within households, organisations, communities, health systems, labour markets and public policy. An individual-level intervention cannot compensate indefinitely for unsafe work, inaccessible healthcare or persistent poverty. The model therefore combines personal adaptation with institutional and structural responsibility.

D. Provisional Model Propositions

- i. Higher multidomain Human Sustainability will predict better functional ability and quality of life beyond conventional biomedical risk measures.
- ii. Emotional Longevity will partially mediate relationships between chronic stress, social conditions and healthy-ageing outcomes.
- iii. Domain interactions will be non-linear, with cumulative disadvantage and protective feedback operating across the life course.
- iv. Women's Sustainability will vary across reproductive, occupational and caregiving transitions and will be shaped by structural gender inequality.
- v. Multidomain interventions will produce more durable healthy-ageing benefits than isolated single-domain interventions in populations with compounded vulnerability.

VIII. DISCUSSION

A. Theoretical Contribution

The principal contribution of this paper is the integration of biological and psychosocial longevity science within a life-course systems framework. Human Sustainability supplies the overarching paradigm, Emotional Longevity specifies a longitudinal emotional construct, Women's Sustainability provides a gender-responsive application, and HSSM specifies interactions and levels.

B. Avoiding Conceptual Overreach

New terminology is useful only if it adds explanatory or practical value. Human Sustainability should not duplicate healthy ageing, resilience or social determinants under a new label. Its validity will depend on demonstrating incremental explanatory value, reliable measurement and usefulness for intervention or policy.

C. Clinical Application

Clinical application could involve a brief multidomain screen identifying biological risk, emotional distress, cognitive change, social isolation, work strain, financial hardship, environmental barriers and loss of purpose. Such screening should guide referral and coordinated care rather than produce a simplistic composite score.

D. Public Health and Organisational Application

Public-health monitoring could complement life expectancy and disease burden with indicators of connection, participation, financial security, caregiving burden and purpose. Workplaces could incorporate sustainable careers, flexibility and emotional renewal into healthy-ageing strategies. Age-friendly planning could connect transport, housing, green space, digital inclusion and social participation.

E. Equity and Cultural Validity

Human Sustainability must not become an idealised standard that blames individuals who cannot achieve flourishing under structural disadvantage. Measures should distinguish personal adaptation from social opportunity and should be validated across cultures, income groups and health states. People living with disability or chronic illness can have high sustainability when they possess autonomy, connection, support and meaning.

F. Limitations

The framework has not been empirically validated, domain boundaries may overlap and causal directions remain uncertain. Composite measurement may conceal important domain-specific patterns. Longitudinal and cross-cultural research is required before clinical or policy thresholds are proposed.

IX. RESEARCH AND IMPLEMENTATION AGENDA

Table 4. Priority research programme for Human Sustainability

Priority	Objective	Recommended method	Expected output
Conceptual refinement	Clarify domain boundaries and propositions	Delphi consensus and interdisciplinary workshops	Consensus definition and model specification
Qualitative foundation	Understand lived meaning across cultures and life stages	Interviews, focus groups and participatory research	Contextualised domain and item pool
Measurement development	Develop reliable and valid instruments	Classical test theory, item-response theory and COSMIN methods	Human Sustainability Index and domain scales

Priority	Objective	Recommended method	Expected output
Longitudinal validation	Test prediction of health span and function	Prospective cohorts and structural-equation modelling	Predictive validity and causal hypotheses
Intervention research	Evaluate modifiable domains and combined strategies	Pilot studies, trials and realist evaluation	Evidence-based multidomain interventions
Women's life-course research	Test gendered transitions and cumulative exposure	Life-course cohorts and intersectional analysis	Women's Sustainability trajectories
Implementation science	Integrate into care and policy	Hybrid effectiveness-implementation studies	Screening pathways, guidelines and service models
Population monitoring	Assess distribution and inequity	Repeated surveys and linked administrative data	National and cross-country indicators

X. CONCLUSION

Longevity science has reached a point at which extending life is no longer a sufficient endpoint. The central challenge is to ensure that longer lives retain functional ability, emotional adaptability, cognitive engagement, connection, participation, security, dignity and purpose.

Human Sustainability offers an integrative paradigm for organising these determinants without displacing the biological achievements of geroscience and precision medicine. Emotional Longevity adds a longitudinal focus on emotional preservation and renewal, while Women's Sustainability makes visible the biological and social transitions shaping female ageing. The Human Sustainability Systems Model unifies these concepts through feedback, accumulation and multilevel context.

The framework should now be treated as a research proposition. Its value will depend on conceptual discipline, psychometric quality, longitudinal evidence, cultural validity and demonstrable usefulness in clinical care and public policy. If validated, it may help shift longevity science from measuring years added to life toward understanding how human capacities can be sustained throughout those years.

XI. DECLARATIONS

Ethics Approval and Consent to Participate

This conceptual review used published literature and did not involve direct participation by human subjects.

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Conflict of Interest

The authors declare no conflict of interest.

Data Availability

No primary dataset was generated. All evidence is available from the cited publications.

Author Contributions

The authors jointly conceptualised the framework, contributed interdisciplinary expertise, reviewed the evidence and approved the final manuscript.

AI and Digital Tool Disclosure

Digital tools were used for language refinement, formatting and reference organisation. The authors reviewed the manuscript and accept responsibility for its accuracy, interpretation and originality.

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