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SUSTAINABLE DEVELOPMENT REVISITED: A CRITICAL REVIEW AND COMPARATIVE ANALYSIS OF CONCEPTUAL MODELS

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Abstract:

Sustainable development emerged as a response to adverse environmental impacts and the failure of traditional models to achieve a balance among economic growth, social justice, and environmental protection. This study examined the historical evolution of the sustainable development concept by reviewing its various stages and highlighting the global agreements and conferences that have contributed to shaping this concept and formulating comprehensive sustainability policies. Moreover, the research reviewed several sustainable development models, including the Triple Circles Model, the Capital Stock Model, the Prism Model, the Sustainability Egg Model, and the Atkisson's Pyramid Model, demonstrating that these frameworks endeavor to balance economic, social, environmental, and cultural dimensions. Additionally, the study discussed criticisms directed at some of these models, notably the Three-Legged Chair Model, which has been critiqued for failing to sufficiently acknowledge the role of humans within the ecosystem. Ultimately, the research concluded that sustainable development represents an inclusive framework aimed at achieving balance across various developmental dimensions, while emphasizing the necessity of equitable resource redistribution and ensuring the sustainability of resource use for future generations.

Keywords: Amoeba Model, Ecosystem Welfare, Social Sustainability, Limits to Growth, Environmental Dialogue.

1. INTRODUCTION

The concept of sustainable development is relatively new, emerging alongside a suite of modern ideas such as governance, the new economy, and civil society, which gained prominence in the context of globalization and its economic, social, and cultural repercussions. This concept was introduced in response to the increasing negative environmental impacts and the failure of traditional development theories which regard growth as the ultimate goal of human activities without considering its effects on the environment and human well-being. Initially, the notion of sustainable development was rooted in environmental concerns; however, it quickly expanded to encompass social, economic, and cultural dimensions.

In today's context, where humanity faces unprecedented challenges such as climate change, natural resource scarcity, and widening economic and social disparities, sustainable development is no longer merely a theoretical model but a necessary approach. These transformations have underscored the need to reassess the foundations of economic and social development in order to balance current needs with the rights of future generations.

This research aims to analyze various sustainable development models and evaluate their effectiveness in addressing the ongoing global economic and technological transformations.

Since its inception, the concept of sustainable development has undergone several developmental stages, marked by the contributions of various organizations and institutions that today work intensively to implement its principles and objectives. The historical progression of the concept can be traced through the following key milestones:

A. **1972 – United Nations Conference on the Human Environment (Stockholm Conference):** The sustainable development concept made its first appearance during this conference, where the relationship between the economy and the environment was discussed under the notion of "eco-development." This pioneering conference, attended by 113 countries, aimed to secure a global political consensus on environmental issues. It also presented scientific evidence on environmental degradation resulting from human activities, thereby raising environmental awareness in industrialized nations, particularly in North America and Europe. The conference sought to globalize environmental issues and involve developing countries in the international environmental dialogue (Hens and Nath 2005). Although the Stockholm Conference underscored

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the integrated nature of environment and development, only 8 out of 109 recommendations explicitly addressed these issues, predominantly focusing on reducing the potential environmental costs and addressing the concerns of industrialized nations (Adams and Thomas 2009).

In the same year, the Club of Rome published its seminal report, *Limits to Growth* (Meadows et al. 2018), which asserted that the continuation of economic growth under prevailing economic models would eventually confront the limitations of available resources, thereby causing environmental damage.

B. **1982 – United Nations General Assembly's Adoption of the World Charter for Nature:** This charter was designed to guide and correct human activities impacting the environment, emphasizing that environmental consequences must be taken into account when formulating future development plans and policies (Robinson 2020).

C. **1987 – The Brundtland Report (*Our Common Future*):** For the first time, the term "sustainable development" was officially introduced in this report by the World Commission on Environment and Development. The report stressed the inseparability of development and environmental issues, recognizing that development could undermine the environmental resources upon which it depends, and that environmental degradation, in turn, could jeopardize development. The report proposed a redefinition of economic growth one that is environmentally and socially sustainable to resolve the dilemma of growth that compromises development (Brown et al. 1987).

D. **1992 – United Nations Conference on Environment and Development (Earth Summit, Rio de Janeiro):**
This conference served as a formal declaration of sustainable development, marking a significant shift in the global discourse by recognizing that development which disregards environmental constraints is inherently harmful. Compared to Stockholm, the world in Rio was markedly different Cold War tensions had subsided, public environmental awareness had significantly increased, and issues such as ozone layer depletion and climate change had become central to global politics. Additionally, energy emerged as a major concern for economic security in the wake of oil price shocks (Soroos 2023).

E. **1997 – United Nations Framework Convention on Climate Change (Kyoto Protocol):** Adopted in Japan and entering into force in 2005, the Kyoto Protocol mandated that developed countries in transition to market economies reduce their greenhouse gas emissions by 5% by 2012 relative to 1990 levels. The Protocol introduced three mechanisms joint implementation, emissions trading, and clean development to help developed countries lower the costs associated with their emission reduction commitments (Gupta 2016).

F. **2000 – United Nations Millennium Summit:** Held at the United Nations headquarters in New York, the summit saw representatives from 189 countries adopt the "United Nations Millennium Declaration," which outlined the Millennium Development Goals focused on eradicating extreme poverty and promoting development. The declaration specified eight key areas and 21 targets, thereby establishing an internationally recognized framework to guide national development and cooperation over the subsequent fifteen years, and setting the course for human development in the new century (Shi et al. 2019).

G. **2002 – World Summit on Sustainable Development (Johannesburg):** This summit addressed a wide range of critical issues including water and sanitation, urban and rural development, energy, science and technology, climate, community responsibility, and water resource management which was prioritized on the agenda. Recognized as one of the most complex United Nations-organized conferences on the environment and sustainable development, it also focused on essential policy tools such as capacity building, technology transfer, training and education, new partnerships, and financial instruments (Hens and Nath 2003).

H. **2012 – United Nations Conference on Sustainable Development (Rio+20):** This conference, which adopted the slogan "The Future We Want," was moderately successful in charting a course toward a sustainable future. Multiple organizations including the World Trade Organization, the Organization for Economic Co-operation and Development, and the International Institute for Sustainable Development supported the concept of sustainable development as one based on three balanced pillars: environmental, social, and economic sustainability. Accordingly, sustainable development requires the following:

1. **Logical Environmental Sustainability:** The level of environmental quality necessary to sustain environmental activities and the overall quality of life (e.g., environmental protection, reduction of pollutant emissions, rational resource use, etc.).
2. **Social Sustainability:** The preservation of social and cultural identity, respect for cultural, ethnic, and religious diversity, and the maintenance of equality.

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3. **Economic Sustainability:** The preservation of natural, social, and human capital required to generate income and maintain living standards (Tomislav 2018).

I. **2015 – United Nations Conference "Transforming Our World":** This conference established the Sustainable Development Goals (SDGs) for 2030, comprising 17 goals and 169 targets. It radically redefined the traditional perspective on development by shifting the focus from solely economic growth to a broader concept of inclusive growth and sustainable development one that integrates economic, social, and environmental development in a coordinated manner (Shi et al. 2019).

In summary, the historical review of the emergence of the sustainable development concept reveals that it is a relatively new idea that has evolved gradually in response to the intertwined relationship between humans and their environment. To sustain this relationship, sustainable development emphasizes the necessity of achieving an equilibrium among the following components: integrating social and economic development within environmental constraints, addressing the demand aspect through equitable resource redistribution to ensure quality of life for all, and considering the needs of future generations by ensuring the long-term availability of resources.

2. **What Is the Concept of Sustainable Development?**

The concept of sustainability in ecology is particularly significant in botany, where "sustainability" is linked to the continuous evolution of plant communities. This dynamic is often employed as a model for managing forests and rangelands. The central premise is that environmental management can benefit from an understanding of natural succession, thereby allowing the application of our ecological knowledge to various areas of environmental management, notably in fisheries and forest management (Redclift 1993).

Development, in this context, refers to a social condition within a state in which the actual needs of the population are met through the sustainable and efficient management of resources and natural systems. This encompasses ensuring that different social groups have access to essential services such as education, housing, healthcare, and nutrition (Mensah and Casadevall 2019).

From an economic standpoint, development involves creating job opportunities that enable individuals to satisfy their basic needs, coupled with the fair distribution and redistribution of national wealth in a manner that promotes social justice. The concept further asserts that the legitimacy of governmental systems extends beyond mere legal frameworks to include their capacity to deliver social benefits to the majority of the populace (Reyes 2001).

In recent years, sustainable development has attracted global attention, thereby facilitating its implementation. One of the challenges in defining sustainable development lies in the ambiguous and contested nature of the term "development" itself. The concept of sustainable development gained considerable momentum in the 1990s, a period during which it was widely believed that conventional developmental paradigms had reached an impasse. Consequently, diverse definitions of sustainable development have emerged, reflecting varying perspectives; however, they universally converge on the idea of achieving long-term endurance and continuity.

Sustainable development is also characterized as a process of change whereby resources are aggregated, investment directions are determined, and coordinated emphasis is placed on technological advancement and the functioning of various institutions. This coordinated process, in turn, enhances the capacity to meet human needs and aspirations (Vare and Scott 2007).

Alternatively, sustainable development is described as a dynamic process that enables all individuals to realize their potential and improve their quality of life in ways that simultaneously protect and enhance the earth (Adams and Thomas 2009).

Furthermore, sustainable development is defined as a set of guiding principles intended to ensure that future generations can continue to progress, particularly in relation to environmental integrity (Bajdor 2012).

MODELS OF SUSTAINABLE DEVELOPMENT

1. **The Three Circles Model**

   Also known by alternative names such as the "three pillars" or "triple bottom line," this is one of the most well-known sustainable development models. According to this model, sustainable development is based on only three dimensions: environmental (conservation), economic (growth), and social (justice). It focuses on the fundamental aspects of human society, as illustrated in Figure (1). However, the model does not take into account the "quality of human life." In this framework, sustainable development is achieved when all pillars operate in harmony. This approach has, however, attracted the following criticisms (Thatcher 2014):

   - The model assumes that the "pillars" are independent structures. Some authors argue that since humans are biological beings, human resources are also part of the environmental resources; consequently, society and the environment are mutually complementary.

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- Natural resources are not independent of one another, and the vast majority of resources utilized by humans are provided in the form of ecosystem services derived from nature. Therefore, it is not possible to separate human development from environmental development.
- The model does not incorporate a temporal dimension, which is an essential component for defining the pillars, aside from their various labels.

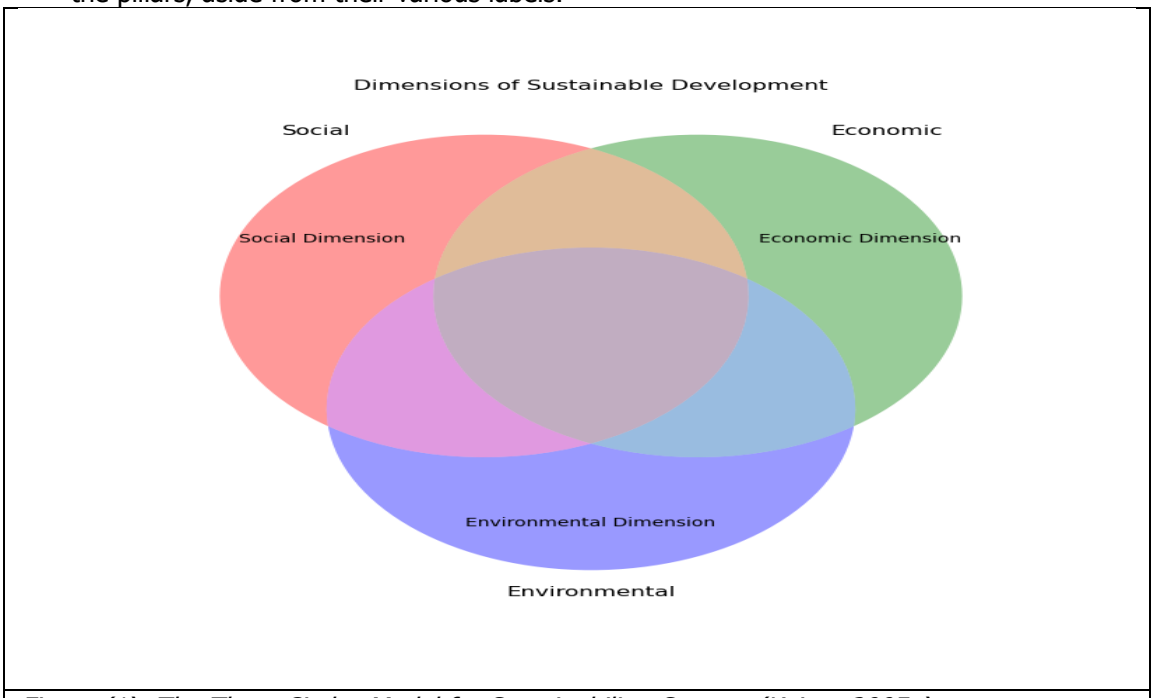

Figure (1): The Three Circles Model for Sustainability. Source: (Keiner 2005a)

This model has been criticized for not accounting for dynamic changes over time, rendering it unsuitable for assessing long-term sustainability. It also assumes that the balance among the environment, the economy, and society is fixed, whereas in reality, priorities and resources evolve over time.

2. **The Capital Stock Model for Sustainable Development**
   In 1994, a research team affiliated with the World Bank developed what is known as the Capital Stock Model. The fundamental idea behind this model is that if society lives off the interest generated by its capital rather than consuming the capital itself, the basis of prosperity will be preserved. However, if materials are consumed, our long-term survival becomes jeopardized (Keiner 2005b). The model is expressed by the following equation:

$$CSD = \sum (CEn + CEc + CS) \qquad (1)$$

where:

- CSD : Sustainable Development Capital
- CEn : Environmental Capital
- CEc : Economic Capital
- CS : Social Capital

The equation underlying the Capital Stock Model assumes that one form of capital can substitute for another. For example, overall sustainable development (CSD) could increase if the rise in economic capital (CEc) outweighs the decline in environmental capital (CEn). This perspective reflects the "weak sustainability" view, which has been widely criticized by environmental economists. These economists argue that environmental capital (CEn) must remain intact for sustainability to be achieved, and that economic capital (CEc) and social capital (CS) should likewise be preserved as they are (Lawn 2000). The criticisms directed at this model include its failure to emphasize the role of laws, regulations, and governmental policies in achieving sustainability. It also assumes that the three dimensions environment, economy, and society automatically move toward a state of balance, without taking into account the influence of public policies and legislative measures.

3. **The Alternative Prism Model for Sustainability**
   Proposed as an alternative to the traditional sustainability triangle, the Prism Model posits that sustainable development rests on four dimensions (Spangenberg and Bonniot 1998):

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1. The economic dimension (man-made capital)
2. The environmental dimension (natural capital)
3. The social dimension (human capital)
4. The institutional dimension (social capital)

This model faces similar criticisms to those directed at the Three Circles Model. It demonstrates that it is practically impossible to increase human capital, social capital, and natural capital simultaneously by the same amount. Instead, the focus should be on the interactions among the four dimensions to create the potential for sustainable development (Stenberg 2001).

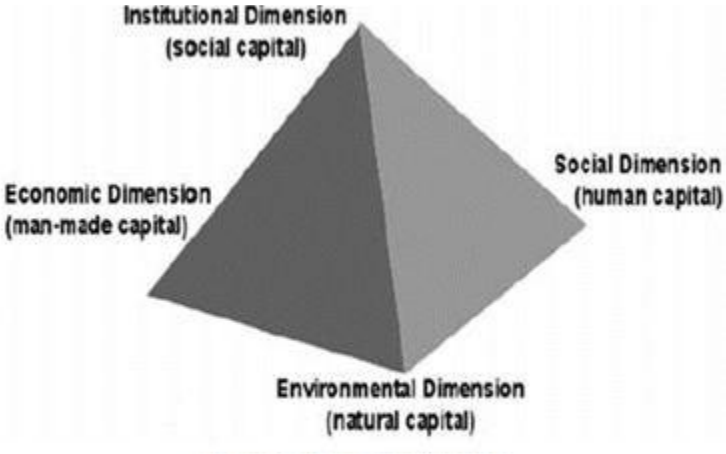

Figure (2): The Sustainability Prism Model. Source: (Stenberg 2001)

4. **The Sustainability Egg Model (and Decent Living)**

Developed by the International Union for Conservation of Nature (IUCN) in 1994, the Sustainability Egg Model reflects the integration of humans with their ecosystems as a fundamental condition for achieving sustainable development. According to this model, the well-being of a community depends on the health of its ecosystem, with both forming an integrated unit akin to the yolk and the white of an egg as shown in Figure (3). The model emphasizes that balancing the utilization of natural resources with environmental preservation is crucial for ensuring both economic and social sustainability. Environmental resources, such as raw materials, land, and economic production, along with ecosystem services including health, recreation, and new job opportunities, form the basis of sustainable development. Therefore, any deterioration in one aspect will adversely affect economic and social stability, thereby necessitating development policies that harmonize economic growth with environmental conservation (Guijt, Moiseev, and Prescott-Allen 2001). This model serves as a critique of the Prism and Three Circles Models, which are said to pay insufficient attention to the environmental dimension (natural capital). For many, the environment is the essential prerequisite for human well-being; thus, the ecosystem must be regarded as the overarching framework within which other dimensions (social, economic, and institutional) can thrive. In this model, the sustainable development equation is expressed as:

$$Sustainable\,Development = Human\,Well\ being + Ecosystem\,Well\ being \quad (2)$$

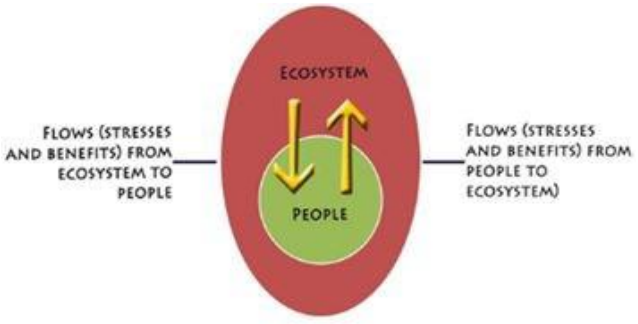

Figure (3): The Sustainability Egg Model. Source: (Guijt and Moiseev 2001)

A similar model, akin to the Egg Model, was independently proposed in which "the economy and society" replace "people" in the yolk (Busch-Lüty 1995). These models position the ecosystem at the center, reflecting the rationale that without a healthy ecosystem, social and economic well-being cannot be sustained. Although these models are abstract

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and simplified representations of reality, they have been widely employed in spatial planning to advocate for diverse development options.

5. **The Three-Legged Chair Model**
   Also known as the "triple bottom line" perspective, this model offers a very simple representation of sustainable development by depicting the environment, the economy, and society as the three separate legs of a chair. If one leg is shorter or longer (i.e., considered more or less important) than the others, the chair becomes unstable (although it might remain usable for a time). Conversely, if one leg is missing, the chair simply will not function. However, if all three legs are of equal length indicating that environmental, economic, and social considerations are given equal weight the result is a well-balanced chair that can serve its purpose indefinitely a truly "sustainable" chair (Herath and Rathnayake 2019).

One criticism of this model is its failure to encourage individuals to recognize their place within the broader ecological context. By promoting equal balance between economic needs, social well-being, and the environment, the model may inadvertently allow current unsustainable trajectories to continue (Dawe and Ryan 2003).

Figure (4): The Three-Legged Chair Model. Source: (Pouresmaieli, Qarahasanlou, and Ataei 2024)

6. **The Amoeba Model**
   This model is used to visually assess the status of a system in comparison to an optimal state. It adopts a circular pattern with various indicators arrayed around the perimeter, with radiating lines extending from the center representing the non-sustainable state to the outer edge, which indicates sustainability. The circle delineates optimal conditions. This type of model allows for the simultaneous evaluation of multiple indicators and facilitates easy comparison among different system components. The "Amoeba Model" is regarded as a powerful technique to accelerate innovation and training, thereby enhancing the effectiveness of sustainable development initiatives (Zeinal Hamedami 2015).

Figure (5): The Amoeba Model. Source: (Zeinal Hamedami 2015)

7. The Atkisson's Pyramid Model for sustainability focuses on addressing sustainability challenges through an iterative problem-solving process. This model aims to accelerate and support progress by beginning with the identification of sustainability visions, followed by analysis and brainstorming, and culminating in agreements based on a reliable action plan (Chinedu, Wan-Mohamed, and Ogbonnia 2018). Its hierarchical structure delineates a series of systematic steps that commence with establishing a robust foundation of understanding, then move on to collecting and researching relevant information, and finally involve the identification and refinement of ideas that are effective, significant, and feasible all while ensuring that all stakeholders reach consensus on these ideas.
   The pyramid is composed of five distinct levels:
   - Level One (Indicators): Measuring trends.
   - Level Two (Systems): Linking causes with effects and identifying leverage points.

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- Level Three (Innovations): Generating ideas that make a difference.
- Level Four (Strategies): Transforming ideas into reality.
- Level Five (Actions): Moving from workshops to real-world implementation.

Figure (6): Atkisson's Pyramid Model, Source: (Herath and Rathnayake 2019)

As illustrated in Figure 6 (Herath and Rathnayake 2019), this model is designed to help groups rapidly ascend the sustainability learning curve—from foundational principles and frameworks, through systems analysis, to the development of innovative strategies for action. In this process, groups engage in cross-sector collaboration, build essential networks, generate dozens of new ideas, and work towards achieving an "agreement"a set of actionable steps that they commit to implementing in the real world.

Table 1 presents a comprehensive overview of various sustainable development models by outlining their key components or dimensions, main focus, advantages, and limitations or criticisms. This table (Table 1) serves as a quick reference guide that helps the reader grasp the fundamental characteristics of each model as discussed in the literature. By summarizing the theoretical underpinnings and practical critiques, the table facilitates an understanding of how each model contributes to or falls short in addressing the multifaceted nature of sustainability. This overview is particularly useful for comparing models side-by-side and identifying which frameworks may be most applicable under specific contexts or planning scenarios.

Table 1: Overview of Sustainable Development Models Key Components, Main Focus, Advantages, Limitations, and References

Reference	Model	Key Components/Dimensions	Main Focus	Advantages	Limitations/Criticisms
(Keiner 2005a; Thatcher 2014)	Three Circles Model	Environmental (Conservation), Economic (Growth), Social (Justice)	Balancing the three core dimensions of sustainability	Simple, widely known framework; emphasizes holistic balance	Lacks a temporal dimension; does not address quality of human life; assumes static interrelations
(Keiner 2005b; Lawn 2000)	Capital Stock Model	Environmental Capital, Economic Capital, Social Capital	Maintaining and assessing sustainability via preservation of various capital forms	Provides a quantitative framework for resource assessment; highlights substitutability among capitals	Reflects a "weak sustainability" approach; substitution of capitals can undermine environmental integrity
(Spangenberg & Bonniot 1998;	Prism Model	Economic (Man-made Capital), Environmental (Natural Capital), Social	Integrating four dimensions to capture a	Offers a more nuanced view by including	Difficult to increase all forms of capital simultaneously; complex

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Stenberg 2001)		(Human Capital), Institutional (Social Capital)	broader perspective of sustainability	institutional dimensions	interdependencies may limit practical application
(Guijt et al. 2001; Busch-Lüty 1995)	Sustainability Egg Model	Ecosystem at the center; juxtaposes human society (or, in an alternative version, economy and society) with the ecosystem (yolk/white)	Emphasizing the central role of a healthy ecosystem in ensuring social and economic well-being	Visually intuitive; underscores that without ecosystem health, human and economic well-being cannot be sustained	Can be seen as overly simplistic; may not capture the dynamic interactions between all factors
(Herath & Rathnayake 2019; Dawe & Ryan 2003)	Three-Legged Chair Model	Three legs representing Environment, Economy, and Society	Illustrating that a balanced approach is needed for stability (each "leg" must be equal)	Simple metaphor that conveys the importance of balance among key sectors	Criticized for not adequately emphasizing the human role within the broader ecological context; overly static representation
(Zeinal Hamedami 2015)	Amoeba Model	Dynamic, circular layout with multiple indicators arranged radially from a non-sustainable center to an optimal periphery	Providing a flexible, visual tool for the simultaneous evaluation of diverse indicators	Enables quick, comparative assessment across multiple system components; fosters innovation and iterative improvements	May require comprehensive data inputs and frequent updates; complexity can increase with the number of indicators
(Chinedu, Wan-Mohamed, & Ogbonnia 2018; Herath & Rathnayake 2019)	Atkisson's Pyramid Model	Five levels: Indicators (measuring trends), Systems (linking causes with effects), Innovations (differentiating ideas), Strategies (turning ideas into reality), Actions (implementation)	Accelerating sustainability progress via an iterative, systematic learning process	Systematic, actionable framework; promotes cross-sector collaboration and rapid advancement along the sustainability learning curve	Implementation may be resource-intensive; success depends on stakeholder collaboration and consensus-building

Table 2 offers a side-by-side comparison of the sustainable development models with a focus on several key dimensions: the incorporation of a temporal perspective, adaptability to global changes, inclusion of policy or legislative aspects, and applicability in spatial planning. By highlighting these specific criteria, Table 2 (Comparative Dimensions and Applicability of Models) provides insight into how each model performs in real-world scenarios and in addressing dynamic sustainability challenges. This comparison is beneficial for researchers and policymakers who need to select or adapt a model that best fits their context, ensuring that the chosen framework is both theoretically robust and practically implementable.

Table 2: Comparative Dimensions and Applicability of Sustainable Development Models Temporal Aspects, Adaptability, Policy Inclusion, and Spatial Planning Relevance

Model	Temporal Dimension	Adaptability to Global Changes	Inclusion of Policy/Legislative Aspects	Applicability in Spatial Planning

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Three Circles Model	Lacks explicit temporal focus	Limited adaptability (static framework)	Not explicitly considered	Commonly used for general planning, though limited in scope
Capital Stock Model	Implies long-term capital assessment	Moderate; depends on capital valuation methods	Indirectly, through the preservation of capital types	Useful for quantitative assessments in planning
Prism Model	Implicit, via multiple dimensions	Moderate; more nuanced than triangular models	Institutional dimension may encompass policy aspects	Offers a more comprehensive framework for planning
Sustainability Egg Model	Static representation	Limited; primarily conceptual	Minimal; focuses on ecosystem-human balance	Employed for advocacy in spatial planning
Three-Legged Chair Model	Static representation	Limited; assumes fixed balance	Lacks consideration of legislative impact	Utilized as a simple metaphor in planning
Amoeba Model	Dynamic, adaptable	High; iterative and flexible	Not explicitly addressed; can be integrated with policy tools	Suitable for complex, dynamic planning scenarios
Atkisson's Pyramid Model	Explicitly dynamic (iterative process)	High; structured to adapt over time	May incorporate policy aspects during strategy and action levels	Highly applicable due to its actionable framework

DISCUSSION

Through a review of the historical evolution of the sustainable development concept and the various models proposed over the past decades, it becomes evident that sustainability is no longer merely an option; it has become a fundamental necessity for confronting the growing economic, environmental, and social challenges. Achieving sustainable development requires the adoption of integrated policies that consider the dynamic relationships among the economy, society, and the environment, while reinforcing the role of innovation and technology in supporting these efforts. Based on the preceding analysis, it is apparent that traditional models, such as the Three Circles Model, provide a general framework for sustainability but lack a temporal dimension and the flexibility to adapt to the shifting dynamics of the global economy. In contrast, more advanced models such as the Capital Stock Model and the Attaxon Pyramid Model offer more practical methodologies, as they enable the assessment of resource sustainability over time and their application across various economic contexts. However, no single model can be deemed "the most effective" on a global scale, since the success of any model depends on the unique economic, political, and social context of each country. This reinforces the need to adopt hybrid models that integrate the positive aspects of various theoretical frameworks. In conclusion, ongoing research in the field of sustainable development is essential for developing and proposing more efficient models, exploring new techniques to ensure resource sustainability, and achieving balanced and inclusive economic growth for both current and future generations.

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