STEEP Systems Modelling: A Dynamic Framework for Developing Sustainability Policies

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Abstract

The global aim is to attain sustainability in different fields due to planetary boundaries within which humanity can continue to develop and thrive for generations to come. However, the relationships between the environment and human interactions are complex and intertwined with multiple systems and can be classed as a complex adaptive system. Therefore, sustainability is a complex dynamic concept that is not well understood hence making its implementation difficult for decision makers and policy development. Sustainability has been established to be a multidisciplinary and systemic issue with interactions of multiple systems. To understand the dynamic and complex nature of sustainability, an appreciation of the interlinkages between the environmental, economic and social aspects have been highlighted in literature. However, the interactions of these three systems with the technological and political systems seem to be overlooked. Based on the complexity of these interactions, sustainability cannot be resolved with a reductionist approach. This paper highlights the limitations of the current widely used model of sustainability and combines STEEP analyses with Systems Thinking to develop a more comprehensive paradigm to promote better understanding and contribute to policy development models for sustainability issues in various global trends. When the interactions between the Social, Technological, Economic, Environmental and Political (STEEP)systems are considered, a more complete picture of the sustainability challenge are presented and better understood. The adoption of STEEP systems approach provides more holistic perspectives to sustainability issues, help the policy makers in better understanding, and aid effective policy development. It is a framework that can be applied to any system's transition to sustainability.

Keywords: Sustainability, STEEP Systems Analysis, Complex Adaptive System, Systems Thinking, Policy Development Framework

1. Introduction

The world currently faces the issue of sustainability in most aspect of human interaction with the environment. This is due to planetary boundaries within which humanity can continue to develop and thrive for generations to come [1]. The disturbing reality of the state of the world is outlined in the landmark Millennium Ecosystem Assessment 2005.

The increasing carbon emissions in the environment and the resultant global warming due to human activities is a key global challenge. However, the ecological footprint alone only presents a partial picture of the health and wellbeing of the planet as these are driven by the current social and economic systems. There is a global rethink and re-plan to human approach to development and the best solution to the problem is sustainable development. Sustainability has therefore become a vital aspect for today's world and the future to come. Understanding how to address issues of sustainability is "one of the most significant translational research problems of our time. The foundational challenge of sustainability is the lack of a standard definition for the term. Various definitions of sustainability have added to the confusion with respect to sustainability in people's mind and in the organisations. A collection of different sustainability frameworks, indicators and tools have provided important insights about the outcomes of the sustainability process and in providing analytical and logical designs for sustainability. However, implementing sustainable practices has been overlooked by the majority of the organisations.

Most literature of sustainability agree that there are interacting elements and details these as economic, social and environmental. There is also a consensus that these interactions cause complexities. It is also known that linear approaches are not effective for complex problems as presented in sustainability challenges. Despite this, sustainability remains one of the least understood concepts with

 | DOI: 10.20533/ijibs.2046.3626.2024.0083

varying definitions and contradicting principles, hence making its implementation difficult for decision makers. Sustainability is defined from a long historical process with an awareness of environmental problems, economic crises, and social inequalities. It does not include the core solutions which are the technology and policies that drive the implementation. It also neglects the possible interactions of 'the solution systems' with the other three systems. By ignoring these, the dynamic and complex nature of sustainability is not fully considered in its implementation. Given that the terms sustainability and sustainable development convey different meanings to different people with divergent views, there is a need to ensure that these are incorporated in its implementation. These issues and divergent opinions can be better understood and incorporated in sustainability implementation through framing Sustainability as a complex adaptive system and incorporating the 'whole systems' approach which provides better understanding of their interactions and interdependences, the feedback loops, non-linearity and delays that exists between these systems. This research therefore calls for a modelling approach that seeks to integrate all interacting systems in analysing and seeking solution to sustainability challenges. It advocated for the interactions of the social, technological, economic, environment and policy (STEEP) systems to be included in the analysis and modelling of sustainability challenges using Systems Thinking paradigm [2]. It argues that the adoption of STEEP systems approach provides more holistic perspectives to sustainability issues, help the policy makers in better understanding, and aid effective policy development.

2. Definitions of Sustainability

From a historical perspective, the concept of sustainability was formulated at the first United Nations Conference on the Environment in 1972, but it has only really taken shape since 1987, when the publication of the so-called Brundtland Report ("Our Common Future") clarified the goals of sustainable development. The term Sustainable Development was coined in 1987 by Brundtland Report presented by United Nation. It defined Sustainable Development as, "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" [3 pg. 43]. It can be deduced from Brundtland Report that Sustainable Development is the concept of growing awareness of ecological crisis and addresses the interlinkage between the environment, economy and social well-being. According to [3], these three guiding principles is considered as pillars of sustainability which shows that advancement require humans, nature and economic capital. These three dimensions are mutually proportional to each other in both ways, positive or negative. However, there is no harmony and integration between these three pillars or principle. With the Brundtland Report (1987), there was little doubt about the relevance of the term "sustainable development" within the contemporary debates on development policy and more specifically the environment and resources policy [4]. However, the term sustainability and sustainable development have conveyed different meanings to a different sector of people about current decision that affect the well-being of the people of the future [4].

The predominant approach is to bring the concept of sustainability and sustainable development from the literature to practical aspects and redefine within a particular context. Many factors make the implementation of sustainability difficult and draw conclusions from current literature. Rather, many concepts of sustainability have being proposed to reflect the major issues. Different approaches have different implications for the way in which the issues are handled and draw some conclusions.

3. Sustainability: A Dynamic Concept

The triple bottom line approach is well known in terms of identifying the different indicators of economic, social, and environmental concerns presented as heterogeneous units. Companies, governments, and non-government organisations (NGOs) usually use the triple bottom line model for sustainability issues. The three pillars, namely social, economic, and environmental are the backbone of the triple bottom line used for sustainability aspects. Sustainability will influence with, related to context, innovation by itself, process and capacity to sustain [5]. In organisational context, sustainability should be adopted as a goal and the comprehensive activities of the organisation must be sustainable. It is argued that 'People' are related to the social system, 'Profit' with economic systems and finally 'Planet' in the environmental system. [6] describes the 'Planet' as the need to balance the environmental burden and the capacity of the earth to carry environmental burdens. The author describes 'People' as the communities and workers who have a stake in organisational activities and 'Profit' as all economic activities that create prosperity for the organisation as well as the wellbeing for the employers. Sustainability is therefore, not a top down solution to balance the 3Ps, but rather it is a consensus solution where stakeholders are involved in the decision-making process [7].

In the global context, environmental sustainability is the ability to preserve and protect the natural environment over time through appropriate practices and policies, meeting present needs without compromising the availability of resources in the future. The influencing factors include; air, water and

 | DOI: 10.20533/ijibs.2046.3626.2024.0083

soil pollution; climate change, caused by the excessive amount of greenhouse gases released into the atmosphere due to human activities; the loss of biodiversity; overexploitation of natural resources; and economic models that involve unsustainable consumption. Environmental sustainability therefore occurs when humanity's rate of consumption does not exceed nature's rate of replenishment and when humanity's rate of generating pollution and emitting greenhouse gases does not exceed nature's rate of restoration. From an environmental viewpoint, sustainability can be considered as carrying capacity, that is, the maximum population supportable in a given region, given the ability of the environment to accept waste emissions and resource availability. The carrying capacity of a region is dependent on the demand and supply of natural resources.

Social sustainability involves a focus on the well-being of people and communities. It represents the ability of a society to uphold universal human rights and meet people's basic needs, such as healthcare, education, and transportation. Healthy communities ensure personal, labour, and cultural rights are respected and all people are protected from discrimination. To achieve sustainability, it is necessary to overcome poverty and socioeconomic inequality, discrimination and social exclusion, lack of access to resources, insecurity and conflict and poor governance. In the path to social sustainability, the promotion of systems and policies that can reduce social and economic inequalities play a particularly important role in ensuring equitable access to opportunities and resources for all members of society.

While the economic dimension is the ability of human communities around the world to maintain their independence and have access to the resources required to meet their needs, meaning that secure sources of livelihood are available to everyone. It advocates that economic activities are conducted in such a way as to preserve and promote long-term economic well-being. In practice, it aims to create a balance between economic growth, resource efficiency, social equity and financial stability. Other dimensions represented in literature include: 'ethics', 'technical feasibility', 'political legitimacy' and 'institutional capacity'.

The three dimensions of sustainability can be visualized in different ways. The Ecologist doesn't see the human race as a separate entity from the planet and its resources, but part of it. Their motivations for preserving the planet are that nature and humanity have an inherent value and should be protected because of that. The Environmentalist sees nature or the planet as separate from the human race. It is there for humans, and as such humans should have stewardship over the world. They see the planet as something to be preserved so that humans can survive and evolve. The Economist understands the measures of unsustainability arising from a consumer led culture treating finite resources as an income, but has faith that market forces and a "business as usual" approach will result in a natural crisis aversion occurring; that the system will sort itself out through technological advances if left to its own devices.

4. The Contractions of the Sustainability Concept

Despite the popularity of the concept, the sustainability argument continues to generate controversies [4] as evidenced in the multiple definitions resulting from the growing attempt of stakeholders to understand the concept. The concept of sustainability is also characterised by contradictions, paradox, conflict and divisions between goals and directions.

The paradox of culture and technology is one of the contradictions of sustainability. It is argued that culture as manifested in technology dependence enable, encourage and increase consumption of resources and waste production [8]. On the other hand, technology is also argued to be the solution for the same problem it created [9]. Another contradiction is that despite the amount of information available, the global environment is characterised by uncertainty and incomplete knowledge about sustainability issues such as climate change. This has caused disparity in policymaking processes and lack of a unified approach to sustainability issues.

Intergenerational and intergenerational equity is also argued as another contradiction of the concept of sustainability [1]. Equity, or justice between generations is the ultimate moral principle behind the notion of sustainability as argued by Bruntdland. However, it is argued that the issue of intergenerational equity within the current world population especially as it pertains the Global South is equally important. [9] argue that assuring resources for the future is not feasible if the present generation lack basic needs as witnessed in energy use in Global South countries. [10] and [11] align with this argument and critiqued Brundtland's definition as ambiguous with no consideration for the dynamic complexities of the Global South in the inter- and intra-generational notion (given that her present generation currently live in abject poverty). [12] also argue that the challenges of sustainable development (which include poor health services, high level of poverty, poor quality of education, climate change risk, food insecurity and gender disparities) are highly prevalent in GS. The opinion expressed by [11] and [13] include that the implementation of the sustainability framework would be difficult in the GS who are in the process of industrialisation and hence could negatively impact their development. [11] further argues that the focus of the developing

 | DOI: 10.20533/ijibs.2046.3626.2024.0083

countries is on economic and social aspects of sustainability and not so much on the environmental. Therefore, the understanding and application of the concept would differ in GS and GN. Sustainability goals of the region are conflicting and competing with each other thereby adding to the complexities already present.

Another contradiction of sustainability concept is argued based on individual or collective responsibility [14]. The rights of nation states are fundamental to the modern world order. The conflicts and responsibility of balancing the rights of individual nations regarding global environmental change, are all too evident. An example of this can be constructed using per capita and overall energy consumption which is a critical factor in reducing climate change. The huge disparity in energy use between GN and GS questions on what basis the responsibility for emission reductions be should be decided.

Making sustainability practical and implementable is a significant challenge, given the multidisciplinary nature of the subject as well as the numerous definitions and interpretations of sustainability. Significant efforts have recently been taken in this regard with the adoption of the 17 UN Sustainable Development Goals at the United Nations General Assembly in 2015 (see Figure 1).

Figure 1. United Nations Sustainable Development Goals [15]

In addressing the implementation challenges of sustainability, [16] conceptualises sustainability as a framework that aids actors in the society (policy makers) determine plausible outcomes (pathways) and changes to economic, environmental and social systems resulting from a particular development decision. The authors however point out that the framework is broad with wide range of approaches, understanding and interpretation; therefore, giving rise to divergent views of the concept. The challenges of sustainability in practice as highlighted by [17] include decision makers' priorities and tradeoff between local (socio-economic benefits) and international (COP Agreements) levels stakes. The authors identify available resources and time as important factors in sustainability framework. Following the contradictions of sustainability concept, [18] argue that sustainability issues such as (climate change) are complex and require combined specialists' knowledge that utilise approaches which embrace and integrate multiple viewpoints, subjects, or issues and interrelations at the same time. The authors further argue that the complexity of challenges related to implementation of sustainability often affect many areas, society, result from joint effect of multiple drivers and are interconnected. This leads to what [19] referred to as "wicked problem". The authors concluded that given the difficulty in understanding the present behaviour of a complex system (such as sustainability) that mapping its alternative futures will even be more challenging. There is therefore need to develop tools capable to addressing complexities of sustainability when applying it to any field.

5. Systems Boundaries to Sustainability

Brundtland Report in 1987 [3] touched on the use of technology and the policy aspect of sustainability, however, the models developed on sustainability fail to incorporate these as systems. They continue to focus on the integration of the environmental, social and economic systems to improve the quality of life within earth's carrying, regenerating and assimilating capacity. Furthermore, the current models fail to acknowledge that the three components do not carry equal weighting but rather the environmental dimension is pre-conditional for both the social and economic sustainability. The current definition and models also fail to acknowledge the fact that each of these systems has a numerous nested hierarchy of subsystems; each subsystem is a whole on its own and forms an integral part of a complex system. The properties of each of these subsystems greatly change when interact with other subsystems. As a result, the properties of a single subsystem cannot be used to explain the properties of the whole system. Therefore, the concept of sustainability falls beyond the narrow scope of reductionism and compartmentalised specialisation. The issues addressed by sustainability are complex with multidimensional variables and sub variables, contradictory and difficult to solve [19]. Their complexity can be better understood and managed, using a systems approach [20], [21]. The integration of the identified systems STEEP in sustainability would aid understanding, practical application and clarify a few misconceptions surrounding the concept of sustainability. The paper proposes a systems model that incorporates the STEEP components for the concept of sustainability.
The pillars of sustainability are closely interconnected, such that every action taken within each of the spheres has feedback effects on the others. There is a strong interconnection between the environmental and economic dimensions, where good

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environmental practices, such as responsible resource management, are essential to maintaining the stability of the economy and the very existence of the food supply chain. The social dimension is equally connected to both the environmental and economic spheres. It is well established that sustainable and resilient economy foster an equitable and inclusive society, where inequalities are reduced and active citizen participation is encouraged. Likewise, there is a strong link between people's health and well-being to the quality of the environment in which they live.

6. Findings and Discussions

The main findings of our research work, sustainability is framed as a complex problem, nevertheless the adapting nature is ignored. The systems boundaries addressed in most framework is limited to economic, social and environment. This neglects the new dynamics and interconnections that technology and policy can introduce to the existing systems.

6.1. Loophole in Framing Sustainability Challenges

The ways in which sustainability challenges are framed can influence how they are acted upon. Framing is "the process by which people develop a particular conceptualization of an issue or reorient their thinking about an issue" [22 p. 103]. It is an unfolding process of meaning-making where the categorisation of a complex reality occurs. Myopic attention to challenge framing has performative implications on action. By overlooking the value of framing, eventual responses may not only fall short; they may even displace, prolong, or exacerbate situations by further entrenching unsustainability.

Complex sustainability challenges may never be fully solved, rather requiring continuous, adaptive, and reflexive engagement over time. Engagement of this nature departs from well-structured problems that entail expected solutions and shifts towards ill-structured or ill-defined issues characterized by wicked problems [19]. Prominent approaches to tackling wicked problems include transdisciplinary (TD) knowledge production, where actors across sectors, disciplines and perspectives mobilise around a shared challenge or question of concern in context.

It is important to understand the extremely complicated relationships between sustainability components in detail. The current framing of sustainability is based on complex dynamic system rather than an adaptive system, or complex adaptive system (CAS). A complex dynamic system is a system that exhibits complex behaviour over time, often involving non-linear relationships and unpredictable outcomes. While CAS is a special case of complex systems, composed of many interacting components that can adapt and evolve in response to their environment. These systems are often characterized by non-linear interactions, feedback loops, and the ability to self-organize. The premise is to understand the extremely complicated relationships between sustainability components in detail. This paper finds that the current boundary in existing sustainability framework is limited to just the 'problem' systems and excludes the 'solution' systems. In doing so, if fails to capture the interactions of the 'solution systems' (technology and policy) and their unintended consequences into the system behaviour.

Complex adaptive system (CAS) is a better framing for sustainability as its implementation is interactive and dynamic. This is rapidly forming a new paradigm which can help in understanding and modelling the multi-layered structure and emergence of sustainability challenges. CAS theory was proposed in 1994 by Professor John H. Holland. The theory claims that the agents of the system have dynamic and changeable characteristics and the ability to interact with other agents, so as to adapt to the surrounding environment and continue to change its own system and composition, eventually evolving into a new system. Conceptually, CAS theory also involves ideas from systems thinking, such as feedback loops, with the understanding that these fields constitute similarly holistic methods of viewing problems [23]. CAS theory is not only an appropriate tool for sustainability policymakers but is also capable of providing insight for organisations. A CAS consists of the qualities of emergence, self-organization, adaptive coevolution, self-similarity, dynamic non-linearity, and systemic interconnectedness.

The core idea of CAS theory is that "Adaptation builds complexity" [24]; Holland also regards the basic units of a system as "Adaptive Agents" which interact with each other and environments to drive the system's development and evolution. Therefore, the idea of "Adaptive Agents" proposes a new way of understanding the relationship between "entity" and "relationship". Interaction is defined as mutual action, effect or influence that may exist between two or more systems [Cordier et al. [25]. There are three patterns of interaction in a CAS: non-linearity, self-organization and emergence; the three patterns are mutually dependent.

Self-organisation: Within CAS frameworks self-organisation refers to the spontaneous emergence of both new structures and forms and new elements emerging at various points and times. These changes may be incremental or dramatic in nature as they adapt to and change according to reactions between subsystems and with other systems. This is usually spontaneous through interactions and interrelationships whereby a system's elements and agents interact and recombine. The capacity for self-

 | DOI: 10.20533/ijibs.2046.3626.2024.0083

organisation is a function of (among other things) the number and intensity of these interrelationships and interactions which could result in behaviour that never stabilises into a recognisable pattern. Conversely, too few interrelationships and interactions could result in frozen behaviour rather than dynamical self-organisation.

Emergence: Emergence is the development of creative, innovative, novel and coherent patterns and properties during the process of self-organisation from the different interaction, interconnection and interdependencies between the different systems in CAS. This happens as new behaviours emerge. Emergence is unpredictable and this is fundamental to and one source of surprise in CAS. Emergence results from non-linear dynamics generating new properties at the macro level of analysis. Emergence is regarded as a holistic phenomenon because the whole is more than the sum of the parts and is the results of agents interacting and mutually affecting each other.

Non-Linearity: As there is no over-arching framework work that controls the flow of information, interactions are rich, non-linear and there is the ability to exchange behaviour. Non-linear feedback is agents' ability to both give and receive responses to their own and other agents' behaviour. Understanding CAS necessitates the search for and understanding of patterns of non-linear relationships where the different inputs are not proportional to outputs and where small efforts to change systems could lead to big effects. Conversely, large efforts might result in little or no change. This non-linearity is very often the result of both positive and negative feedback systems which operate in CAS where one agent's activity can influence that agent as well as other agents. In non-linear relationships simple deterministic equations might produce an unexpected richness and variety of behaviour. On the other hand, complex and seemingly chaotic behaviour could lead to ordered structures and/or patterns. In non-linear equations prediction is very often impossible, even though the equations might be strictly deterministic.

6.2. The STEEP Systems Interactions

STEEP stands for social, technological, economic, environmental and political (policy) factors interactions within a given system. Each of these systems is a whole system on its own but a subsystem when met with another part [2]. The whole system is greater than the sum of its constituent parts and each part is critical for the existence of the whole system [26]. Each system is interconnected to form a complex system.

The natural environment is a self-regulatory system with a complex network of positive and negative feedback systems that function within the context of carrying, regeneration and assimilation capacity of the respective system [27]. The realization that natural resources are finite and humans need to live within a certain capacity has led to the need for sustainable practices. Without these services and resources, social and economic systems will not be possible. It is therefore important to identify and assess the traditional environmental aspects such as carbon and water footprints, air pollution and greenhouse emission [28]. Policies such as climate regulation are used to protect the environmental system.

The economic system depends on the human and physical resources from the social system while the social system relies on the economic system for the transformation of raw material for consumption. The economic and the social systems transform resources into waste through resource-intensive consumption. Waste is stored and assimilated through the environment system. This is the cause of emission and the source of other major challenges, which threaten the global atmosphere and other life-support systems.

The environmental, social and economic systems are closely linked, interact and overlap. These interconnections indicate the 'wholeness' of the systems and crucial feature of the relationships between the systems. As the environmental system approaches its limit, there is a need to maintain a balance between environmental (the pre-condition for the other two systems) and social systems, which provides the platform for socio-economic activities.

The technological system is used to abate the impact of the interactions of the economic and social system on the environment. It includes challenges of adoption, speed of transfer, innovations, efficiency, carbon footprint, cost and culture. The uptake of technology can be improved by political alignment, regulations, legislation, and policies, which can gear investment or support (subsidy) that influence the society towards a particular technology.

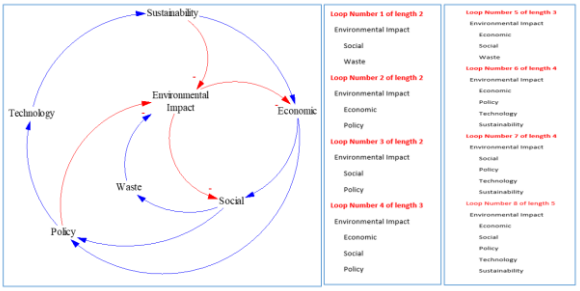

Figure 1. Interconnectedness of the STEEP Systems

7. Application of STEEP Systems Analyses as a Sustainability Framework

Complex adaptive systems thinking (CAST) is adapted in the application of STEEP systems modelling. CAST is an analytical approach that

takes into account the features and elements of a system, how they work together and how they influence each other. It fosters development of dynamic leaders and dynamic solutions in all environments, as the leader must take a holistic approach to the issue by visualising how a solution will impact the rest of the system. A system can be a community, an ecosystem, a city, or even a network like a political party, or geopolitical organisation. This thinking process breaks any system down into four components:

- Multiple Perspectives: personal beliefs, world views, voices, knowledge and culture that exist in a system.
- Influences: barriers, leverage points, drivers, attitudes and stakeholders within a system.
- Interconnections: relationships, patterns of behaviour and networks within a system.
- Boundaries: communities, systems within systems, issues and scope of the mission that limit a system.

Recognition of how these four components relate to and rely on each other brings awareness to the interconnectedness of all actions and how influencing one component could have potential consequences to another. The most commonly suggested advantages of this approach are that it: challenges assumptions, focuses on relationships rather than simple cause and effect models, can be applied in a variety of contexts, provides a framework for categorising and analysing knowledge and agents, suggests new possibilities for change and provides a more complete picture of forces affecting change.

8. Conclusion

The concept of sustainability demands a shift to a new perspective; the need to frame sustainability as a complex adaptive system thereby integrating all interrelated systems (STEEP). Sustainable development must encompass all parts and feedbacks in a system or there is a possibility that warning of important leverage points will be missed. Developing strategies that drive society toward whole system sustainability, requires recognising that systems are more than just the sum of their ecological, economic or social parts. This paper attempts to advance the understanding and practical application of the concept of sustainability by analysing the systems involved in sustainability and showing the interrelationship between the five systems (STEEP) and the importance of each subsystem using Systems Thinking casual loop diagram to model the multiple perspectives, influences, interactions and map boundaries that include all the systems.

9. References

[1] Rockstrom et al. (2009). Planetary boundaries: Exploring the safe operating space for humanity". Ecological Society, 14, no. 2, pp32.

[2] Nwankwo, N., Olaniyi, T. K., and Morgan, A. (2022). STEEP Analysis of Energy System Transition to Sustainability. International Journal of Sustainable Energy Development, No. Issue 1, 2022 .

[3] WCED. (1987). Our Common Future, World Commission on Environment and Development (Brundtland Report) United Nations, Oxford University Press, UK.

[4] Atkinson, G., (2008). Sustainability, the capital approach and the built environment. Building Research & Information, 36(3), pp.241-247.

[5] Wiltsey Stirman, S., Kimberly, J., Cook, N., Calloway, A., Castro, F. and Charns, M. (2012). The sustainability of new programs and innovations: a review of the empirical literature and recommendations for future research. Implementation science, 7(1), pp.1-19.

[6] Mulder, K.F. (2006). Engineering curricula in sustainable development. An evaluation of changes at Delft University of Technology. European journal of engineering education, 31(2), pp.133-144.

[7] Achman, R. (2011). Stakeholders' Perspectives on Sustainability in Project Management: Case studies of 4 different projects in the Netherlands.

[8] Dovers, S.R. and Handmer, J.W. (1993). Contradictions in sustainability. Environmental conservation, 20(3), pp.217-222.

[9] Dovers, S. R., (1996). Sustainability: demands on policy. Journal of public policy, 16(3), pp.303-318.

[10] Mebratu, D., (1998). Sustainability and sustainable development: historical and conceptual review. Environmental impact assessment review, 18(6), pp.493-520.

[11] Olaniyi, T. K. (2008). Decision Support Systems for Sustainable Energy Planning in a Developing Economy, Ph.D Thesis, London South Bank.

[12] Edomah, N., Bazilian, M. and Sovacool, B.K. (2020). Sociotechnical typologies for national energy transitions. Environmental Research Letters, 15(11), p.111001.

[13] Johnson, K.A., Dana, G., Jordan, N.R., Draeger, K.J., Kapuscinski, A., Olabisi, L.K.S. and Reich, P.B. (2012). Using participatory scenarios to stimulate social learning for collaborative sustainable development. Ecology and society, 17(2).

[14] Dovers, S.R. and Handmer, J.W. (1993). Contradiction -s in sustainability. Environmental conservation, 20(3), pp.217-222.

 | DOI: 10.20533/ijibs.2046.3626.2024.0083

[15] United Nations (UN). (2015). Ustainability. UN.

[16] Davidson, K.M. (2011). Reporting systems for sustainability: what are they measuring? Social indicators research, 100, pp.351-365.

[17] Ebenhack, B.W. and Martinez, D.M. (2013). The path to more sustainable energy systems: how do we get there from here? Momentum Press.

[18] Willamo, R., Helenius, L., Holmström, C., Haapanen, L., Sandström, V., Huotari, E., Kaarre, K., Värre, U., Nuotiomäki, A., Happonen, J. and Kolehmainen, L. (2018). Learning how to understand complexity and deal with sustainability challenges–A framework for a comprehensive approach and its application in university education. Ecological Modelling, 370, pp.1-13.

[19] Rittel W. J., and Webber, M. (1973). Dilemmas in a General Theory of Planning", Policy Sciences, Vol. 4, No. 2 (June), pp. 155-169.

[20] J. Liu et al. (2015). Systems integration for global sustainability. Science, vol. 347, no. 6225, p. 1258832, 2015.

[21] Dovers, S. R., and Handmer, J . W. (1996). A Typology of Resilience; Rethinking Institutions for Sustainable Development. Industrial Environmental Crisis Quarterly, Vol 9, No 4.

[22] Chong, D. and Druckman, J.N. (2007). A theory of framing and opinion formation in competitive elite environments. Journal of communication, 57(1), pp.99-118.

[23] Ellis, B. S., Herbert, S. I. (2011). Complex adaptive systems (CAS): An overview of key elements, characteristics and application to management theory. Inform. Prim. Care 2011, 19, 33–37.

[24] Holland, J. H. (1995). Hidden Order How Adaptation Builds Complexity; Addison-Wesley: New York, NY, USA.

[25] Cordier, S., Debarsy, N., Ertur, C. (Eds.) (2017). Understanding Interactions in Complex Systems: Toward a Science of Interactions; Cambridge Scholars Publishing: Cambridge, UK.

[26] Checkland, P. (1999). Systems Thinking, Systems Practice. New York: Wiley.

[27] Meadows, D.H., Meadows, D.L., Randers, J., and Behrens, W.W. (1972). The limits to growth. New York: Universe Books.

[28] IPCC. (2018). Summary for Policymakers. Global Warming of 1.5°C. An IPCC Special Report World Meteorological Organization, Geneva, Switzerland, 32 pp.

 | DOI: 10.20533/ijibs.2046.3626.2024.0083