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On Developing Sustainable Digital Ecosystems and their Spatial-temporal Knowledge Management

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Full research paper

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Abstract

The research aims to assess the sustainment between multiple domains and ecosystems with viable and adaptable models. We propose an Information System (IS) modelling approach and examine the sustenance between ecosystems through connectable multidimensional IS artefacts. For example, humans survive in healthy and hassle-free environments for long-term economic benefits. We conceptualize human, healthcare, and environmental ecosystems are connectable, and the interconnectivity depends on how the ecologies are supportive together and with each other. The ecosystems develop with data heterogeneity challenges, which can disorganize ecological connectivity, impeding the implementation of resilient digital ecosystems. The development of multidimensional repositories is an added motivation, and to explore connectivity, we have sought Attribute Journey Mapping and Modelling (AJMM) method. Map views are computed to successfully interpret and establish connectivity, including coherency between attributes of multiple domains. Besides, Big Data has changed the ecological research direction with which the coexistence between human-healthcare-environment ecosystems is assessed.

Keywords: Sustainability, Information System, Digital Ecosystem, Knowledge Management

1 Introduction

The environment within which human ecosystems survive may connect coexisting ecological domains and systems in an inclusive knowledge space with spatial-temporal dimensions. Interconnectivity between human, healthcare and environmental ecosystems is an obscured phenomenon (Burke 2013). Factually, the phenomenon describes that various diseases can occur within the environment that affect the existence of human beings. Designing and developing a variety of schemas relevant to these ecosystems are pathways for establishing interconnectivity. With the support of various graphic tools, attribute Journey Mapping and Modelling (AJMM) is used to ascertain the phenomenon of interconnectivity between multiple digital ecosystems. The concept of sustainability evolves that can interpret periodic sustainment of human survival, although the impacts of diseases in polluted environments are widespread. Interlink between systems is interpretable with coexisting associations, and each association influences the other (Banitz et al. 2022). The sustainable association implies that human survival depends on the pristine environment to offer healthy and safe community service. Pristine implies a healthy natural environment. However, human activities can not only construct the environment but can make it disorderly, where the human habitat struggles to exist (Jianping et al. 2014). The phenomena interpret that the ecosystems are connectable, implying they are embedded (Banitz et al. 2022). We further intend to illustrate the phenomenon through connectable Information System (IS) articulations. We propose IS constructs and models to interconnect multiple coexisting ecosystems through Design Science (DS) approach (Peffers et al. 2020; Nimmagadda et al. 2017). In addition, for interconnecting human-healthcare-environment domains and systems through IS artefacts in spatial-temporal dimensions, we take advantage of Big Data, as these ecosystems embrace volumes and varieties of data sources in varieties of geographies and demography (Malpass and Reinhart 2022). Big Data guided repository systems are designable with various IS artefacts and are usable for data mining, visualization, and interpretation purposes to add value to new knowledge. Digital ecosystems have led us to decipher ecosystem knowledge and its sustainment through ecosystem evaluations (Stuermer et al. 2017). The current research scope and domain are broad and multidimensional. Intrinsically the research does not confine to a particular domain. For example, human ecosystems though broadly describe human environments, but healthcare and natural environment influence human existence ecologically. The real challenge is to interpret and measure the impact of coexistent ecologies on human survival. Salient feature of the research lies with the facts of connecting these ecologies through IS articulations. Traditional IS research cannot resolve the challenges of assimilating the coexistence between ecologies; thus, the authors develop sustainable digital ecosystems to manage connectable spatial temporal knowledge. Before discussing the components of framework development, we describe the concepts and context of sustainable digital ecosystems in the following sections.

The idiom sustainment is a composite entity purposely interpreted to assess ecological systems and their digital transformation. We take advantage of the concept of an ecosystem through an integration process in a sustainable knowledge-space environment. Sustainability relates to the viability and manageability of ecologies that benefit humans for extended periods, including green living. The phenomenon envisages the design of ecosystems and their integration in common knowledge space. The design process can further strengthen the investigation of the sustainment of ecological systems and their digitization process, including the interdependence between coexistent systems (Stuermer et al. 2017). The digital ecosystems are data-driven and spatial-temporal (Bibri 2019). Besides, sustainability is the capacity of a resource to endure, regenerate and flourish through the time dimension (Burke 2013). The research further emphasizes that sustainability can influence the control of cultural systems and how they interact within broader ecological settings. Oliver (2015) describes how the data sources are structured to manage and produce improved data science and ecosystem knowledge for decision support systems. From a repository system perspective, sustainability is viewed as a composite attribute, implying that sustainability-associated problems cannot address efficiently in a single domain. Whether it is a system viewpoint of one demography or culture of a human ecosystem or an environment in which the human ecosystem survives with other coexistent systems. Sustainability explicitly implies generating economic values or attaining benefits for an extended time-period. Even though the concept of sustainability is evolving, ambiguity persists in its interpretation, even compromising the communion, connectivity, and interaction among multiple systems. Besides, the boundaries between ecosystems can explicitly be interpretable from data science and knowledge engineering perspectives. We summarize Big Data tools can underpin the sustainability concept with data storage technologies and data-mining articulations through a unifiable ecosystem framework.

2 Literature Review

We examine the existing literature through the conceptual and contextual engagement of the design science approach. The innovative intercommunity framework uses Design Science – Information System (DS-IS) articulations, in which various connectable IS constructs and models are designable to develop and implement in domain applications (Elmsalmi et al. 2021). The DSIS is articulable to manage multiple digital ecosystems, establish their connectivity and ascertain sustainability phenomenon with varying attribute dimensions and their modelling (Christakis and Fowler 2013). The digital tools and technologies are described, offering data-driven solutions, and preserving natural science analytics (Arts et al. 2015). Sustainability manifests as dependence between multiple ecosystems in diverse scenarios (Christakis and Fowler 2013). Big Data concepts and tools have allowed us to investigate large volumes and various ecosystems data sources (Ritchie et al. 2020). Data relevant to nature, people, integration process, and green environment are critical details of the research framework used in leveraging the sustainability. Transitions to sustainable development have occurred historically, even though diseases have affected human ecosystems (Alonso-Fradejas 2021). The effect includes threatening livestock, and growing cognizance of the risks and veracities of climate change, including energy and food crises (Jianping et al. 2014). The research aims to bridge the gap between observation and explanation on providing intelligence with a committed seminal socioeconomic and technological development. On the other hand, multidisciplinary analytical heuristics and concepts are accessible for policy intelligence (Grin et al. 2010).

In the IS perspective, sustainability is a function of the overall strength of artefacts, designed and implemented through specially designed data schemas (Nimmagadda and Rudra 2016). Peffers et al. (2018) describe the theoretical conceptualization of IS artefacts and their implications in industry contexts. Cross-domain research components are discussed in Burke (2013). Zheng (2015); Cerovšek and Matjaž (2014) have conducted cross-domain research in which multidisciplinary data are fused. Various challenges of implementing new technologies are described in Pimm et al. (2015) to conserve biodiversity. The research has highlighted data acquisition methodologies, integration practices, and data analytics. A quasi-evolutionary model is described for socio-technical transitions, including their governance at various levels of management (Geels 2010; Späth and Rohracher 2012; Ulli-Beer 2013). Different criteria are presented to characterize complex ecosystem problems and for general morphological analysis through modelling and analyzing the problem solutions (Elmsalmi et al. 2021). A comprehensive literature on social science research methodologies explains several quantitative and qualitative approaches (Creswell 2014). Design science research is an affordable prescriptive and descriptive procedure based on which IS artefacts are designable that can deliver new domain knowledge (Baskerville 2015). In an industrial scenario, design science puts effort into creating a new product (artefact), but in most cases, the more successful a project is considered, the less is learned. The effort is desirable to produce a new product using the state-of-practice application with readily available research components. The engineering or design-science process is assured to collaborate with the industry base IS artefacts, filling the gap between design-research and product-design (Peffers et al. 2020). Mixed methods in social research can offer new scopes of investigating multiple ecosystems and developing knowledge on sustainability (Snelson 2016).

3 Problem Definition, Research Questions and Objectives

The current research problem describes broader issues, complexity, and ambiguity attributed to multiple ecosystems and examines the gaps in ecosystem knowledge in spatial-temporal dimensions. We aim to address theoretical and practical problems which can contribute to digital transformation and develop ecosystem knowledge. So far, human, healthcare, and environmental ecologies have been independently known in the literature. But the influence of one ecosystem on the other is unclear. We need to know and assimilate the unified knowledge of multiple ecosystems, assimilating their sustainment and the connectivity between ecological events. The major challenge is however exploring the connections between common attributes, including conceptualized and contextualized features, associated with diverse domains of ecosystems. Essentially, ecosystems hold Big Data, which is spatial temporal. In addition, the ecosystem data are heterogeneous and multidimensional, with hundreds of attribute dimensions in multiple domains with a variety of elements and processes of systems (Banitz et al. 2022). We can arrive at new information solutions by connecting multiple attribute dimensions and instances through multidimensional schemas. The attributes are derived from knowledge-based human-, healthcare- and environment ecosystems. Ecosystem data are unifiable in a repository system, with an assertion to perceive the value of sustainment through coexistent systems. For sustaining ecosystems and resolving associated semantic, schematic, and syntactic heterogeneities, the boundaries are set for the integration process between ecologies (Oliver 2015). Based on the literature review and research issues, we have designed research questions (RQ) and Objectives (RO): RQ1: What is the need for interconnecting human, healthcare, and environment ecosystems through IS artefacts? RQ2: How do we achieve connectivity and evaluate ecosystem sustainment? We use cross-domain research and develop IS articulations and connect ecosystems to understand the sustainability phenomena. RO1: The human, healthcare and environment entities are closely connected (Stuermer et al. 2017). RO2: Having interpreted several attribute dimensions from diverse ecosystems, IS artefacts are articulated to assimilate the relationships between their data ecosystems. Using the AJMM method, we evaluate the artefacts through computed plot and map views with new knowledge of the coexisting ecosystems.

4 Significance and Motivation

Volumes, varieties, and variabilities are typical characteristics of Big Data in digital ecosystem contexts that are spatial-temporal and are used to interconnect ecologies in geographic contexts. Depiction of spatially controlled multiple digital ecosystems relies on Big Data. Various domains of ecosystems can exhibit Big Data characteristics in spatial-temporal dimensions. Velocity is one of the characteristic properties of Big Data, implying rapid movement of data among various ecologies with new IS articulations within an integrated framework to achieve the objectives and goals of the research. The development of the sustainability concept assures the delivery of quality and structured ecosystem information given to humankind for sustained periods (Burke 2013). For example, sustainable population growth must match available environmental resources maximizing the healthy ecologies for extended periods. The scope of such research has motivated us to develop IS artefacts in multiple domain applications with data engineering and industry implementations. Spatial-temporal attribute dimensions and their modelling have further motivated our focus on designing flexible data models to accommodate future changes in multiple ecosystems that describe coexistence, inheritance, and encapsulation characteristics. Minimizing the ambiguity of interpreting new ecosystem knowledge relies on the effective means of IS artefact designs and implementations. The study can promote larger ecosystem projects with sustainable digital ecosystems. The proposed innovative DSIS framework development aims to reduce ecosystem service operational costs, including aligning multiple industry projects and maximizing the value of sustainability through new IS tools and technologies.

5 Research Elements for Sustainable Framework Development

We have acquired and documented the data sources relevant to the elements and processes of multiple ecosystems (Birol et al. 2022; Ritchie et al. 2020). Other challenges are data compilation, integration and sharing valuable knowledge in spatial-temporal dimensions. Organizing, structuring, and integrating the existing data sources in multiple domains of human-healthcare-environment ecosystems are features of the current research. The phenomena of sustainability evolve with environment ecosystems, with various activities and functions of related human ecosystems, including their entities and dimensions with linked data instances. To understand the sustainment of multiple ecosystems, we take advantage of ecosystem entities and dimensions in building various IS constructs and models. We represent these models in periodic dimensions to assess ecological ability and sustainability through an integrated environment. Multiple business entities are brought together in a business management environment in cross-domain research. For example, the human ecosystem can threaten the human-affected pristine environment and other coexistent ecosystems. Therefore, as per RO1, understanding the connectivity between systems in various ecological settings is paramount. To investigate further the shortcomings and challenges of the existing data organization procedures, we plan a logical and methodological approach to design and develop multidimensional schemas and repositories. In addition, cross-domain research can connect geographies and demographies, even through domain ontologies (Geels 2010). Simulation of an integrated framework describes the context of a digital ecosystem, as detailed in Nimmagadda and Rudra (2016). The repository metadata exploits data patterns from massive data stores. Interpreting correlations and trends among metadata of ecosystems within a sustainability framework requires rigorous data analytics. A primary task is to identify and interpret hundreds of existing data entities, dimensions, and their associated thousands of attributes, including their conceptualized attribute dimensions (Arts et al. 2015). We summarize the following elements of framework DSIS development to articulate the sustainability process through connectivity between coexistent diverse ecosystems.

(a) Domain sustainability: Several domains participating in the formulation of ecosystems must be examined to investigate the phenomenon of sustainability. The more domains join the ecosystem representations, the better the discernment of knowledge of interconnectivity between systems (Banitz et al. 2022). In the digital ecosystem perspective, a domain addresses and controls knowledge space or area in which common attribute dimensions and their characteristics are shared among ecologies. To

describe domain sustainability, we explore the other domains closely associated with or connected to the human-healthcare-environment domain application settings. For example, humans are closely related to the environment ecosystem, in which several communicable and non-communicable diseases can be intuitive, affecting the human habitat. These ecosystems can be connectable through common elements and processes of multiple ecosystems, engaging in sustainability interpretation and a common knowledge space (Christakis and Fowler 2013; Bibri 2019). Besides, the human, healthcare and environment are made relatable to meet technological challenges. The economic purviews share a common knowledge space through spatial dimensions.

(b) Data Integrity and Salience: Data association and intelligibility depend on the number of joinable domains and systems, interconnectable in an effective data modelling process that accords with sustainability principles and perspectives (Markulev and Long 2013). Heterogeneity and multidimensionality also affect the data modelling procedures. Data integrity and salience rely on the dynamics of knowledge creation and the way data integrity is maintained within each domain entity—for example, the tolerance needed between human and environmental ecosystems is achievable through knowledge interpretation. The research examines how repositories respond to Big Data, including storage and processing capabilities. Use, reuse, efficiency, effectiveness, completeness of IS artefacts and how their properties respond to different realms in a unified metadata structure are described.

(c) Repository Accessibility and Security: Multidimensional repositories rely on the size and type of Big Data that guide multiple ecosystems, domains, and data models. The process includes how logically and physically the data are structured to unify in a warehouse environment. Often, complex data issues can limit the storage capability; however, the data views can legitimately be interpreted differently, depending on the epistemological framework (Peffers et al. 2020; Markulev and Long 2013). However, the impacts of ambiguity can be reduced when attributes and properties, including their instances, are collaborated to improve the data qualities and domain knowledge. The sustainability of the repository system can affect the interpretation of variable instances and their knowledge mapping. We intend to demonstrate multidimensional repositories (Nimmagadda et al. 2017) in the context of closely linked ecosystems, illustrating how the big data scale up metadata structures sustainably and collaborate the cognitive knowledge and its associated data analytics artefacts.

(d) Knowledge Cogency and Adequacy: The cogency and adequacy of knowledge rely on the involvement of diverse systems, domains, data sources and repositories described within the apprehension of holistic digital ecosystem development. When considering the human-healthcare-environment structural setting applications, the knowledge relies on the facts of indulgence between multiple ecosystems and their data models, including the instantiation process of a sustainable DSIS framework (Markulev and Long 2013; Stuermer et al. 2017). Spatial-temporal dimensions of diverse models can leverage the sustainability theory. The knowledge interpreted in the form of areal extents of ecosystems and their boundaries has immense scope in strengthening business viability and ecological sustainability. The ability of connectivity and interaction between ecosystems can further facilitate improved management and production of data science for decision support systems.

(e) Business Viability: Though business sustainability, in the current research, is beyond the scope of ecosystems' investigation, we intend to provide the impact of human-healthcare-environment setting on business sustainability (Geels 2010). Business viability analysis can only occur when closely associated domains of multiple digital ecosystems, data sources, and sizes can leverage unified levels of sustainability-informed knowledge management (Markulev and Long 2013; Stuermer et al. 2017). Prior knowledge of the domain and data may help assess business opportunities. For example, the knowledge obtained from closely related human, healthcare, and environment domain applications, is analyzable. The manner IS artefacts sustain for more extended periods is made viable in larger geographic and demographic extents. The sustainment can demonstrate that businesses can survive for longer periods based on viable parameters (Elmsalmi et al. 2021).

(f) Ecological Function and Resilience: A concept of a resilient ecosystem and its functions are described to improve environmental monitoring and management (Oliver 2015). Ecological resilience recognizes the facts of diverse surroundings and the ability of systems to resist and maintain the functions as described in (a) – (e) (above). However, ecosystems are emerging, evolving, and dynamic with time-period. Consequently, from an information system and informatics perspective, the sustainability framework reconciles with the goals of more resilient ecologies that can create synergies within ecosystem domain applications. The degree to which an ecosystem function can accommodate or recover rapidly in environmental perturbations or human-induced disturbance is analyzed so that ecological activity that is made sustainable can attain economic outcomes in clean energy environments.

6 Research Methodology and Framework Development

We have followed Design Science as a research methodology in the current research (Peffers et al. 2018). Several citations are given on the DSR approach from which several constructs, models and methods emerged along with the instantiation process. The artefacts are mere simulations deduced from the DSR approach. The instantiation process can facilitate testing the artefacts and iterating them through updated data sources. The Design Science Information System (DSIS) is developed from the generic DSR method to resolve the present ecosystem complexity (Nimmagadda and Rudra 2016). Qualitative and quantitative interpretations of secondary data instances acquired from multiple ecosystem contexts are used in the instantiation process. Big Data can guide the DSIS approach that can integrate domain ontologies described from multiple domains of human-healthcare-environment ecosystems. The repository design, domain and data modelling, data mining, visualization and interpretation are other key components of the DSIS framework development. The development of IS artefacts that support domain ontologies for managing multiple heterogeneous ecosystems is the focus. The development motivates the use and reuse of constructs and models in sustainable interoperability and data analytics tools. From the digital ecosystem perspective, the simulatability of the human-healthcare-environment and its construction is explored within the DSIS framework with associated IS artefacts (Nimmagadda and Rudra 2016). Further, an understanding of ecosystems with connectable functions is emerging with dynamics of ecology, life sciences and with continued demand and supply of information, articulating the sustainable environment (Burke 2013). The volumes and variety of heterogeneous and unstructured data emerge to hypothesize the phenomena (Figures 1a and 1b). Managing such enormous data sources and extracting new knowledge from the ecosystems is a significant challenge. Once resolved, it would considerably benefit decision-makers across global businesses. For example, we hypothesize players of sustainability with connectable components through their data sources (Figure 1). The arrow's direction depicts how each player guides the other in a common framework.

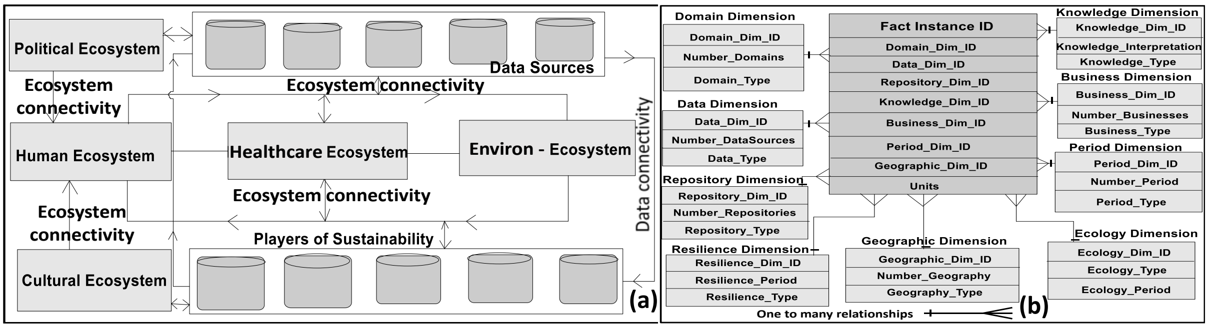

Figure 1 (a): Players of sustainability with connectable data sources (b) Sustainable big data characteristic dimensions

Different attribute dimensions are interpreted from Big Data sources, covering activities and functions of ecosystems, and articulating their associativity through various IS artefacts (Nimmagadda and Rudra 2016). Ontologies are used to interconnect multiple ecosystems (Buttigieg et al. 2016). In the information System perspective, data acquisition, storage, processing, and deliverable new information are various tasks with attributable dimensions (Curry 2016). The advent of Big Data concepts and tools and the research of digital ecosystems has taken a new direction to unearth vast data into further information and knowledge. Hundreds of data attributes and instances are usable for building IS constructs and models. The digital ecosystems are simulated using integrated framework articulations with associated schemas or artefacts (Peffers et al. 2020; Nimmagadda et al. 2017). Various dimensions, attributes, and fact instances are incorporated with Big Data characteristics. We examine multiple components of the digital ecosystem simulations that required developing the DSIS and how sustainable they are in warehouse repositories, so the endurance and combined impacts ecosystems can aptly be assessed. Further, we describe the phenomena of ecosystems through the integration of artefacts (logical and physical schemas) and various components involved in unifying their digital contents. We construe the attribute dimensions of the framework, demonstrating connectivity through a star schema as an IS artefact (Figure 1b). From the informatics perspective, the critical aspects of sustainability and its analysis may be viewed as a function of the domain (context), data integrity and salience, repository accessibility and security, knowledge cogency and adequacy, business viability and ecological function and resilience. In the information system (IS) perspective, sustainability is proportional to the strength of artefacts (domain, data model, data warehousing, data mining, visualization and interpretation, new knowledge, and business value).

We emphasize that ecosystem-sustainability concepts are relatable, and sustainability lies with facts of good governance and cultural systems (Figure 1a). They interact with coexistent ecological systems to foresee broader ecosystems by integrating data sources and producing ecosystem knowledge for policymaking purposes, as in Stuart et al. (2015). The attributes associated with food security, social order, economic growth, gender equality, optimum use of resources, human development, energy and power, infrastructure, transportation, and urban design are relatable to sustainable research projects (Stuermer et al. 2017). The criteria motivated us to categorize the current ecosystem research: human, healthcare and environment coexistent ecosystems and unify their data sources in a common framework. The additional criteria discussed in Section 5 (from (a) to (f)) have motivated us to construct IS artefacts for each domain of the ecosystem. Several attribute dimensions are used in building the IS artefacts (RO1). An innovative framework needed to implement the meld between human-healthcare-environment ecosystems in a shared digital ecosystem is discussed in the following sections.

7 Implementable Integrated Framework in an Ecological Knowledge Space

Data come from multiple domains and ecological systems, for which we gathered volumes, variety and variable data published by various agencies. We have documented the data in multiple files in rows and columns to store, process and unify across clusters of computers in metadata structure using HADOOP and MapReduce. Several data mining and visualization models are generated using a variety of mining and graphic tools. As described in stages 1-6 in Figure 2, we have done mapping modelling of data in spatial dimensions. Around 150 countries' geographic and 50 years of periodic data were acquired and documented to test IS artefacts, evaluating the phenomena of human-healthcare-environment ecosystem interconnectivity (Nimmagadda et al. 2017). We analyze the human-healthcare-environment communities through the DSIS guided ecosystem approach. The AJMM method is used to identify and assimilate the attributes from the data sources through the mapping and modelling process. For mapping and modelling the ecosystem data sources, conceptualization and contextualization features can set the limits of the connectivity process among human ecologies that are affected by various diseases and environmental impacts. For example, in "pandemic" contexts, the manner human activities affected the overall ecosystem communities is examined through spatial dimensions and Big Data tools. During DSIS implementation, we infer that infectious pandemic diseases affect the healthcare ecosystem and the interpretation of interconnected human habitats and environmental ecosystems. Implementable IS artefacts and DSIS articulations are updated through iterative procedures based on evolving pandemic data attribute instances and the damage they have caused to human and environmental ecosystems.

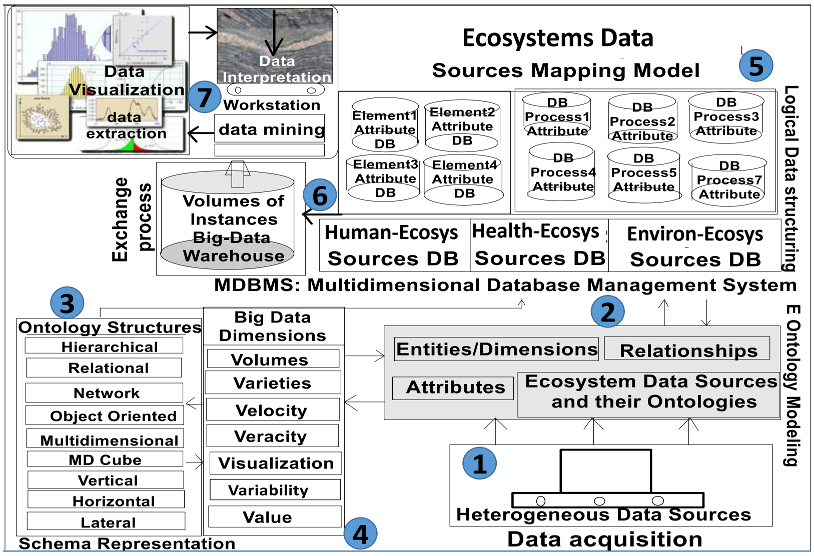

Figure 2: Implementable AJMM framework for assessing the sustainable digital ecosystems (RO1)

We formulate the artefacts, domain-, data-modelling, schema selection, warehouse design, data mining, visualization, and interpretation in the DSIS integrated framework. Each framework component performs a particular task, as described in Figure 2. Several deduced are deduced in the sustainability DSIS framework. The stages are (1) Data acquisition (2) Building relationships and ontologies between attributes (3) Different ontology structures, (4) Big Data characteristics (5) mapping and modelling the ecosystem data attributes (6) – (7) data mining, data visualization and data interpretation, all performed in a single canvass (Figure 2). The attributes interpreted within human-healthcare-environment ecosystems collaborate with the components of the DSIS framework (Figure 2). The DSIS framework is flexible enough to support the implementable IS articulations in the embedded human-healthcare-environment ecosystem settings. We have mapped and modelled the attributes that contributed to spatially varying sustainability processes (Markulev and Long 2013; Stuermer et al. 2017). As a part of the instantiation process of the DSR approach, in the empirical modelling, we have tested IS artefacts through an iterative process so that the artefacts and the framework used are robust and holistic in analyzing multiple digital ecosystems. Using various data mining and visualization techniques (Stuart et al. 2015), we have computed plot and map views to evaluate the connectivity between multiple ecosystems and their sustainability (stage 7 of Figure 2). Interconnectivity and interdependence between diverse and sustainable ecosystems are assessed.

8 Results and Discussions

Graphic tools provide validity of mining models. Data qualities have been checked through qualitative and quantitative trends of data that make sense of new knowledge interpretation. Temporal sustainability is an inherent concept that construes knowledge-based attribute strengths observed over varying time-periods that infer periodic divergence. As discussed in Figure 3, we used various northing and easting coordinate attributes to arrive at interpretable map views that oblige the spatial sustainability models (Bibri 2019). As per RO2, several envelopes, numbered 1, 2, 3, 4 and 5, interpreted as close and distant clusters, assess connectable attribute areas (Figure 3).

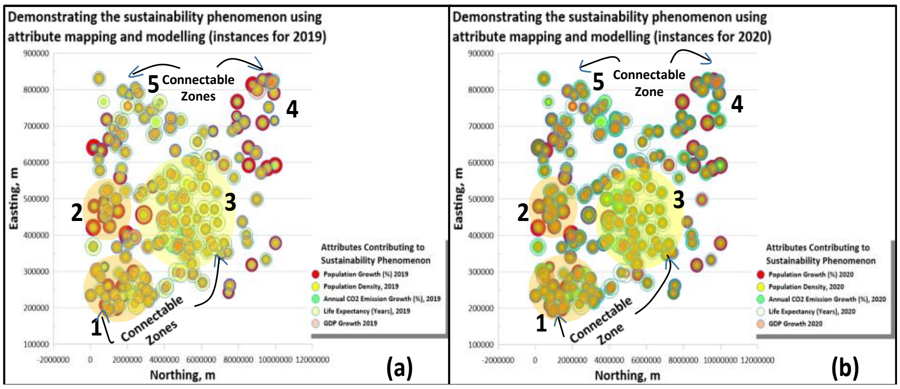

Figure 3: Bubble plot views between population growth, life expectancy, annual CO2 emissions and the GDP growth attributes in sustainable spatial dimensions for years (a) 2019 and (b) 2020 (RO2)

Stage 7 of Figure 4 has significance in visualizing and interpreting plot and map views. As shown in Figure 4, we have drawn a couple of bubble plot views. We construe an increase in food production with time-periods with increased CO_2 emissions and the global rise in temperatures (Figures 4a and 4b).

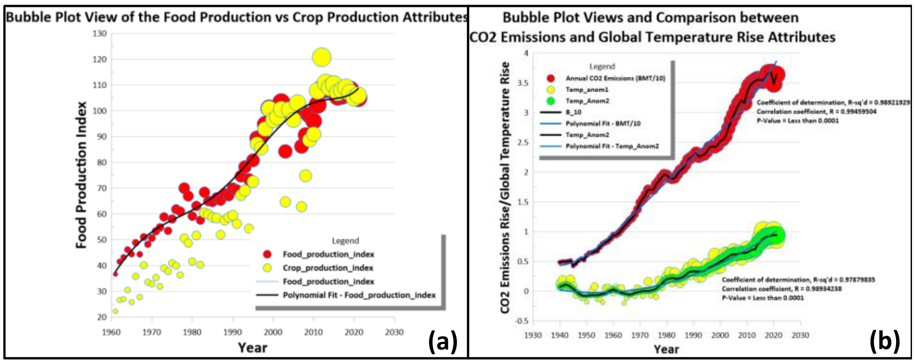

Figure 4: Bubble plot views (a) food and crop production attributes and (b) CO2 emissions and the rise in global temperatures in temporal sustainability phenomena (RO2)

Map views are presented to understand the existence of human habitats in spatial dimensions. An increase of 43% in CO_2 emissions is observed, though it does not imply a global rise in temperature due to emissions. However, it isn't easy to interpret the global rise in temperatures due to manufacturing activities or natural means. Besides, the analysis done for over 80 years of CO_2 emissions data suggests that, as shown in Figure 4b, CO_2 increase is due to manufacturing activities. From the data considered for 130 years, a temperature rise of 0.8 degrees centigrade is observed. The analysis construes a correlation between CO2 emissions and rising global temperatures. Envelopes interpreted for population growth attribute (P1 to P7) match with life expectancy, annual growth of CO2 and GDP growth attribute envelopes, implying that these attributes have explicable relationships (Figures 5a – 5d). Envelopes P1 to P7, L1 to L7, E1 to E7 and G1 to G7 exhibit comparable associations, establishing interdependence between multiple digital ecosystems. Map views deduced from DSIS sustainable framework (Nimmagadda and Rudra 2016) envisage the implementation of IS artefacts in multiple digital ecosystem contexts. The metadata demonstrates the spatial sustainability between population growth, life expectancy, CO2 growth, and GDP growth attributes. By observing periodic facts, an increase in global temperature is discerned by only one-third compared to a two-thirds rise in 1975.

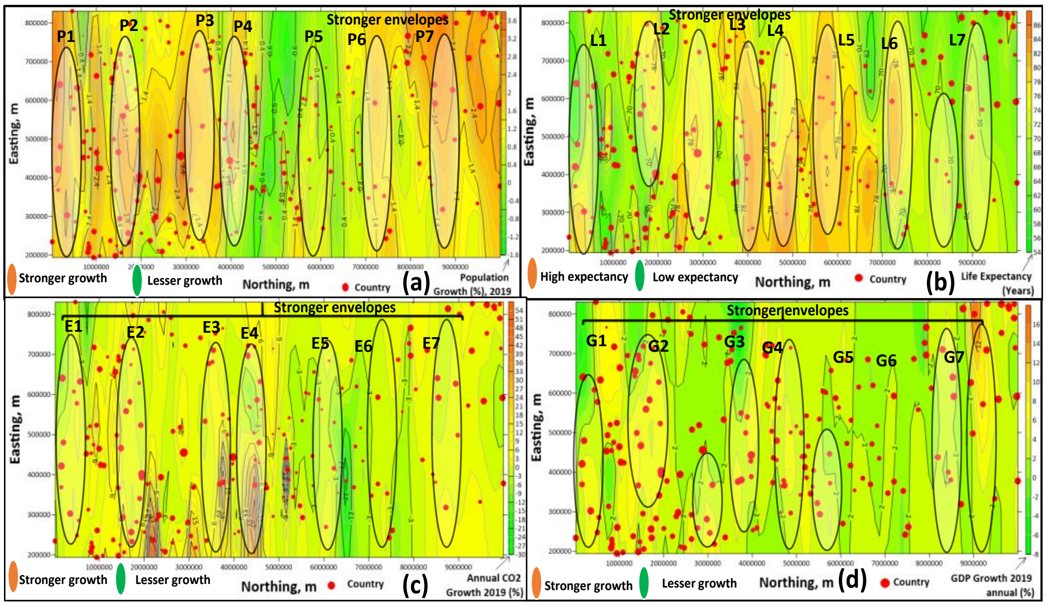

Figure 5: Map views from DSIS metadata – demonstrating the spatial sustainability phenomena (a) population growth (b) life expectancy (c) annual CO_2 growth (d) GDP growth (RO2)

Ellipsoid-shaped envelopes are construed in Figure 5 to envisage various anomalies of attributes in spatial dimensions. Population growth and life expectancy attributes are comparable. Interestingly, the population and CO2 emission growth attributes are comparable (Figures 5a and 5c). As a part of the implementable framework (Figure 2), several maps and plot visualizations demonstrate the connectivity between multiple digital ecosystems through their common data attribute. The attribute instances show strong (red color) and weak (green color) attribute strengths. The population growth, life expectancy (healthcare focus), and annual CO2 growth (with connectable global warning attribute instances), including GDP growth attribute instances, are coherent and correlatable visually. The interpretation is a measure of assessing sustainability in multiple digital ecosystem contexts. The innovative implementation framework brings human-healthcare-environment ecosystem communities together and unifies them in a shared digital ecosystem platform. The artefact design focuses on the DSIS framework development, as presented in Figure 2. Insights of interconnectivity between systems are provided; however, ambiguity persists with the interpretation of the human ecosystem in all its inclusiveness (Stuermer et al. 2017). In our research, spatial-temporal data, for example, population growth, different ages and gender attributes in human ecosystem perspectives, viral, chronic, and infectious disease attributes in healthcare ecosystem perspectives, and CO2 emissions and the global rise in temperature attributes, are considered. Spatial-temporal dimensions control these attributes. The integration process, interconnecting multidimensional schemas pertinent to human-healthcare-environment ecosystems within the DSIS framework, has facilitated us to demonstrate and develop the phenomenon of sustainability in embedded digital ecosystem contexts and knowledge management. Big Data features and components discussed in Figure 2 are supportive as per design-science guidelines and evaluation properties (Venable et al. 2016). Various fine-grained data views are presented for interpreting the knowledge-based digital ecosystems.

9 Research Audience and Contribution to Theory and Practice

Information system researchers and enthusiasts of sustainable ecosystem research, service providers, and data analysts are the research beneficiaries of the current study. For managing the ecosystem resources and their knowledge, the DSIS approach is holistic and includes interrogating various human, healthcare (diseases) and environmental and ecological challenges. Tools are compatible with other mechanisms of the IS methodologies. The manner framework can progress forward among research communities and evaluate their articulations is made explicit for future research advancement. Interdependence between multiple digital ecosystems ascertains the value of ecological solutions in interpreting sustainability phenomena. The impacts of human habitat in spatial dimensions contribute to human-ecosystem development, and ecosystem constituents agree with the Big Data guided DSIS framework theory. The research demonstrates the balance between human-healthcare-environment ecosystems without compromising their sustainment, including economic gains in green environments.

10 Limitations and Future Work

The novelty of research relies on managing the sustainable IS articulations in unifying multiple human-healthcare-environment digital ecosystems. The artefacts must be adaptable to sustain digital ecosystems and their presentations. The artefacts developed in each domain must be compatible for unifying the DSIS framework consistently. Data heterogeneity and multidimensionality pose key challenges in the integration process when new domains are added to the DSIS framework for appending multiple digital ecosystems. The data considered in each application must be scalable to logical and physical data organizations, reconciling the data qualities. Interpretation of data views needs special attention in delivering sustainable digital ecosystem solutions. The contextualization features of the sustainability framework are extendable in shaping different coexistent ecosystems.

11 Conclusions

IS approach ascertaining the sustainment of multiple ecosystems, provides new knowledge. Big Data tools and technologies have roles in resolving the ecosystem data complexities, including investigating the coexistent digital ecosystems and their sustainability. The Big Data guided DSIS framework can discern the sustainability between composite attribute dimensions in multidimensional models and evaluate their congruent and coexistent characteristics. Mapping and modelling methodologies have successfully delineated the connectivity between multiple ecosystems through bubble plot and map visualizations, including the AJMM method graphic tools. Data models built based on a particular domain can be extended to other domains, contributing to ecosystems' sustainability and knowledge management. Unless the heterogeneity of multiple ecosystems and their data complexities are resolved, we cannot understand the sustainability between ecosystems and attain their economic benefits.

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