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Information System Guided Supply Chains and their Visual Analytics in Integrated Project Management

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Full Paper

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Abstract

From a digital ecosystem perspective, *sustainability* is a manifestation of a composite entity with multiple data attribute dimensions. The data relationships may emerge between geographically distributed supply chain management ecosystems and their linked human, economic and environment ecologies. The ecosystems may exhibit inherent connections and interactions. For making connections more resilient, we characterize models that serve multiple industries through numerous data associations, even in Big Data scales. In the context of Integrated Project Management (IPM), the knowledge of boundaries between systems is mysterious, analysing diverse ecosystems through a sustainable framework can uncover new insights of inherent connections. The purpose of this research is to develop a holistic information system approach, in which multidimensional data and their connectivity are analysed, recognizing the ontological cogency, uniqueness of ecosystems and their data sources. The research outcome has facilitated the tactical development of strategies for ameliorating the *sustainability* challenges in the IPM contexts.

Keywords: Information systems, supply chains, visual analytics, integrated project management

1 INTRODUCTION

This section provides an introduction to sustainable ecosystems, the motivation for this research. Human survival and well-being depend either directly or indirectly on the ways in which natural resources are nurtured, protected, used and managed in our biophysical and sociocultural environment. There is growing concern about rising social, environmental and economic risks surrounding the existing ecosystem progress, attained through a variety of commonly intertwined modernization processes (Dovers et al. 2001). Sustainability is described with a definite focus on systems, in which human and environment domains coexist in creative and effective symbiosis. Such pertinence enables us to fulfil the cultural, social and economic necessities of present and future generations, respecting sustainable exploitation of natural resources for mankind. In the current research, the structures of Human, Economic, Environment Ecosystems (HEEE) and their affected Logistics and Supply Chain Management Ecosystems (LSCME) are characterized in an architectural framework, in a manner human activities are analyzed in an ecosystem, modelling corresponding economic and environment scenarios that assert their relevance in logistics and supply chain systems. As shown in Figure 1, each player of an ecosystem has the potential to contribute to or detract from the sustainability of the system in which human, economic and environment are a subset. The research emphasizes the human, environment and economic domains/ecosystems as entities from which a connectivity can be established through articulations of Information System (IS) artefacts and their integration in a sustainability framework. The domains are apparently subsets of each ecosystem needed to bring and assemble HEEE and LSCME as fused purviews in the framework with connections as represented by arrows in Figure 1. Figure 1a represents a schematic view of the design of a digital supply chain ecosystem with various concepts and contexts as players of HEEE (Figure 1b), affecting the design and development of supply chains in viable manner.

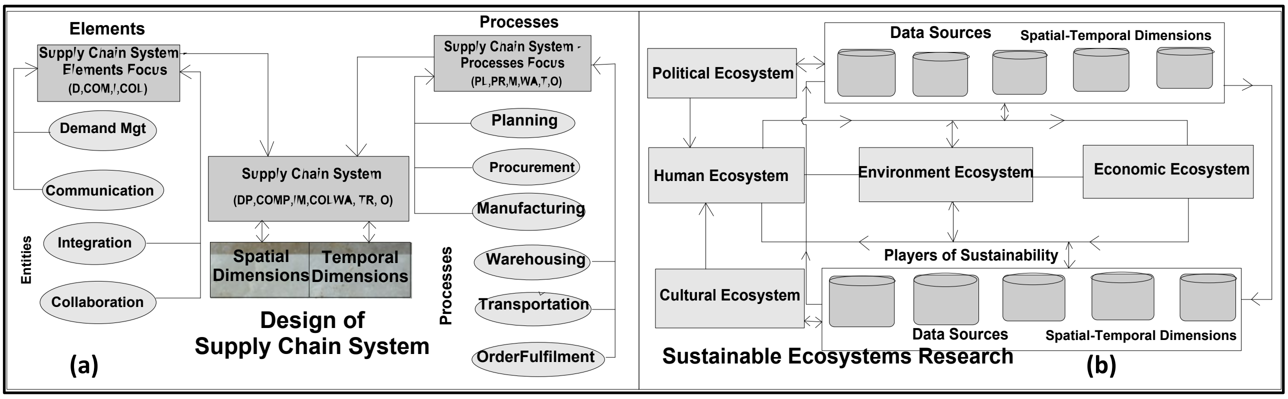

Figure 1: Sustainability and its players in the (a) LSCME (b) HEEE composited domains

Multi-scalable and multidimensional ecosystems (including spatial ecologies) have significance based on a commonality of basic structural units and domains (Burke 2013). The common task of working within diverse ecosystems is a need to analyse big datasets, produced and collected in a varied range of methods to understand particular phenomena and test hypotheses. Generation of more interfaces (both back-office and front-end) in the integrated framework is an added scope for suitably accessing, extracting and analysing data to create useful knowledge and other data services. The primary motivation for researching LSCME is to resolve their complexity, by analysing a vast amount of empirical data instances, domain experts' views, previous researchers' work and multiple stakeholders associated with supply chain networks in spatial-temporal contexts. Human activities occur in multidimensional contexts and domains in particular within prescribed conducive environmental and economic ecosystems' rules and constraints, which are motivational aspects of the system development. The perception of unification across domains can significantly minimise the ambiguity of information needed in the integrated interpretation of knowledge among diverse ecosystems. This process can ease the tactical development of strategies for ameliorating the *sustainability* challenges in the IPM contexts including creating benchmarks and impacts at micro, meso and macro levels in knowledge-based IPM.

1.1 Logistics Supply Chain Management Ecosystems

The LSCME has diverse ecological scenarios that share common domains, attributes and their associated conceptualized and contextualized connection features (Nimmagadda and Rudra 2017). For example, spatial and temporal data sciences may have common attributes in one or more ecosystems' settings that can exhibit favourable connections between domains and systems. The challenge is to uncover such supply chain ecosystem knowledge and how best we can interpret the eventual links between coexistent systems. A conceptual framework is proposed, extending its interpretation and sentiment analysis, including integration to improve and achieve supply chain making decisions and improve their performance (Miller 2015). The authors provide additional empirical research evidence with analytical capabilities. Miller (2015) provides an ecosystem approach with a network of supply chain systems. We present comprehensive and practical insights that can facilitate companies to take advantage of new market opportunities, conquering the supply chain challenges to make better-informed business decisions.

1.2 Human, Environment and Economic Ecosystems

In support of LSCMS architecture (Figure 1a), we particularize the design details with encapsulation of human-environment-economic systems and their domains within a HEEE architecture (Figure 1b). It is articulated with existing data sources and their instances of their elements and processes. In broad terms, human, environment and economic realms are cogitated as different players/agents that can operate within a range of *sustainability* scenarios. This approach recognizes the existing constraints of systems as well as the emerging knowledge of boundaries envisaged in ecosystems in the form of connectable attribute dimensions (Nimmagadda and Rudra 2017), explorable in-between domains and systems of LSCME and HEEE architectures.

2 RELATED WORK AND MOTIVATION

The literature review explores research gaps, drawing the aims and purposes of the research. Though literature exists with regards to Logistics and Supply Chain Management Systems, but in ecosystem scale to describe the LSCME and HEEE architectures, we constrain with limited literature. However, Design Science Research (DSR) and Supply Chain Management (SCM) are mature fields of research, but we intend to explore sustainable ecosystem services with the groups and/or industries that involve IPM. defend the transitions to sustainable development that have taken place with the epic pace of disease events affecting the human ecosystems, threatening livestock, and the growing cognizance of the risks and veracities of climate change, the energy and food crises. The authors have observed the entire chain of events, occurred in social systems with further need of fundamental transformation in systems research. Dovers et al. (2001) describe ecological uncertainties and policies in managing sustainable ecosystems. Pimm et al. (2015) describe various challenges of implementing new technologies to conserve biodiversity. They emphasize data acquisition methodologies, integration practices and data analytics, however lack motivation in connecting systems in the IPM scale. In the current research, we intend to analyse the artefacts in contextualized ecosystems. Vaishnavi and Kuechler (2007) propose specific design-science research that is distinguished from designs of the production system. Engineering research or design-science research (Henver et al. 2004) is intended to amalgamate industry base designs and artefacts, filling the gaps between design-research and product-design. Feasibility of data warehousing applications in industry scenarios were critically examined in Gornik (2002); Coronel et al. (2011); Pujari (2001), providing insights of data modelling, storage with mining methods, with different computing algorithms, and case studies of various company situations. Matsuzawa and Fukuda (2000) describe several data mining techniques such as clustering, associative rule mining and construction of classifiers using decision mining trees. Miller and Han (2001); Ott and Swiaczny (2001) illustrate the use of spatial-temporal datasets and organize them in a warehouse environment to explore data using data mining procedures. Marakas (2003); Nimmagadda and Rudra (2017) provide an outdated synopsis of data visualization with concepts and practical implications of interpretable data views in discerning meta-knowledge.

3 RESEARCH STATEMENT AND MAJOR CHALLENGES

The issues associated with digital ecosystems and sustainability are associated with heterogeneity and multidimensionality of data sources. The critical challenge arises in the semantics associated with data sources of multiple ecosystems and their conceptualisations from which the attributes derived, at times, are hard to define (Meersman 2001). It is because of the complexity of data systems and their attribute fact instances, at times are hard to describe semantically and consistently. Nevertheless, the attribute properties that represent various contexts in multiple domains are interpretable and included in the dimensional data constructs and models. The challenge at given spatial-temporal attribute dimensions is either with LSCME and or HEEE articulations within embedded ecosystem scenarios that prompted us to use or reuse of common definitions of various terminologies, described in different contexts. To understand the terminologies in ecosystem contexts, there may not be a precise meaning across all attribute dimensions in which the ecosystems coexist and function dynamically. As a result, the explorers within that community have either a greater or lesser understanding of the semantics of the data, where it is neither comprehensive nor explicitly defined. However, either LSCME and or HEEE architectures are not defined in a single and consistent logical domain; but composed of numerous largely focused research communities. It is not a significant issue if researchers only retrieved data from a single domain, which is not usually the case in the current contexts of LSCME and HEEE. Analysis of such multifaceted or composited digital ecosystems requires researchers to have access to integrated metadata deduced in diverse domains. For data sources of large communities, the composite domains and attributes can manage typical structure/axiom information: that is, the ecosystem provides a sequence of information with useful annotation, accommodating combination of definitions and evolving terminologies.

The implicit domains in ecosystems' research pose various challenges for data integration, including the challenge of evolving conceptualizations in scientific areas that are not typically addressed elsewhere (Pimm et al. 2015). A first challenge is the large number of available data sources, their inherent heterogeneities and their contexts. Certain sources contain data from a single laboratory or project, whereas others have definitive repositories in particular types and varieties (e.g., for a specific human or environment or supply chain classes). The highly specialised data semantics or ontologies from diverse sources may simplify the concept identification and interpretation, and also make them methodologically feasible to incorporate all of them into a consistent repository with intelligently moulded models (Jarrar and Meersman 2002; Wand 2000). The second significant issue is, data formats and data-access methods may evolve and change frequently. They may occur in the community at large where a change in a data source of one system representation can have an unintended but dramatic impact on other systems that can cause the integration to fail in a new format or structure. Thirdly, the data and their related analyses become increasingly complex as perception of interconnectedness among elements and processes of ecosystems grows – including the 'butterfly effect' where small changes in a variable can have sizable consequences. The new knowledge, for example, may be about renewable resources, their inventory, and sustainability that can facilitate viable, competitive businesses and their alignments. The data relationships in the current research may emerge between geographically distributed SCM ecosystems and their linked human, economic and environment ecologies. The purpose of the research is to examine, articulate and develop Information System (IS) guided SCM with multidimensional artefacts, addressing the issues relevant to endurable connections between multiple domains and systems of diverse industrial ecologies of IPM contexts, which are not addressed elsewhere in the literature.

3.1 Description of Complexity of Ecosystems

We take advantage of the concept of an ecosystem, broadly an integration process in a sustainable environment. Burke (2013) describes sustainability as the capacity of a resource to endure, regenerate and flourish through time. We emphasise that viability depends on understanding the governance, cultural systems, and how they interact within ecological systems, such that they can be better structured and managed to produce data science and knowledge for policy decision-making purposes. From a database systems perspective, sustainability is viewed as a composite attribute implying that sustainability associated problems cannot be addressed efficiently in a single domain. Whether it is system perspective with one demography or culture of a human ecosystem or an environment in which human ecosystem survives with other coexistent systems, the sustainability generates economic values or benefits over an extended period. Even though the concept of sustainability is evolving and dynamic, ambiguity still persists in its perception as well as the communion, connectivity, and interaction among multiple systems within the ecosystem framework. The boundaries can be interpreted explicitly in the data science and knowledge engineering perspectives. In addition, the Big Data tools and technologies underpin the sustainability concept with data warehousing and mining articulations in the integrated ecosystem framework simulations. The environmental imperativeness, economic viability, socio-technical transition and corporate-social responsibility are among other composited attributes of the LSCME and HEEE architectures.

With the arrival of Big Data concepts and tools, research of digital ecosystems has taken a new direction to unearth a vast amount of data into useful information and knowledge. The digital ecosystems are simulated within the integrated framework articulation and its associated artefacts. In this process, various dimensions, attributes, and their fact instances are incorporated in Big Data artefacts and their characteristics represented in spatial-temporal dimensions. We describe the phenomena of ecosystems with the integration of artefacts (logical and physical schemas) and various components involved in the integration of their digital contents. Multiple components of the digital ecosystem simulations are examined leading us to develop a DSIS, how sustainably it can be accommodated in multidimensional warehouse repository, such that endurance and combined impact of the multiple ecosystems can aptly be assessed. To demonstrate the phenomena, we describe dimension characteristics as in Figure 2, representing connectivity in between attribute dimensions. Figure 2 explains various attributes involved in the multidimensional modelling process. Several such schemas can be designed to accommodate and integrate them with the DSIS framework (Nimmagadda and Rudra 2017).

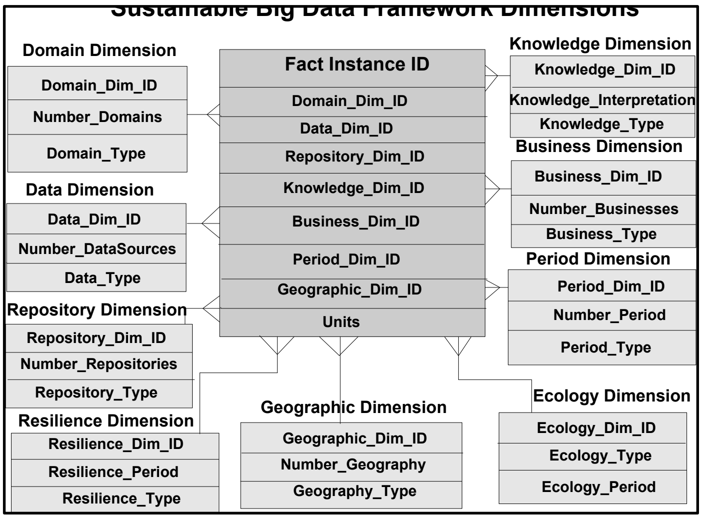

Figure 2: Star Schema model representing the Big Data dimensions

3.2 Intricacy in Data Integration

From a digital 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 IS viewpoint, sustainability is a function of the strength of artefacts (*domain, data model, warehousing & mining, visualization & interpretation, new knowledge and business value*). From an ecosystem perspective, sustainability is a function of *domain context, data integrity and salience, repository accessibility and security, knowledge cogency and adequacy, business viability, ecological function, and resilience*. Exploring the connections between common attributes (including conceptualised and contextualised attributes) of domains of digital ecosystems has many benefits, but it is a challenging task. Data sources pertained to the elements and processes of ecosystems acquired from open and shared data sources are inputs of the integration process. Organizing, structuring, and integrating the existing data sources in multiple domains of LSCME and HEEE architectures are features of the research as envisaged within conventional approaches (Nimmagadda et al. 2018). The systematic investigation and management of data sources using IS tools have motivated us to examine the pitfalls in the current integration process. A methodology is required that can elucidate the data patterns from unorganized and unstructured volumes of massive data stores. There is an opportunity for cross-domain research in bringing and connecting diverse domains, even organizations through domain ontologies (Burke 2013). Interpretation of patterns, correlations and trends among ecosystems' data sources within a sustainability framework have led us to rigorous analysis of scientific information. Simulation of an integrated framework is described in such contexts of a digital ecosystem. An integrated scheme, the DSIS within a sustainability framework can provide an innovative integrated solution for managing various digital ecosystems in the IPM scenarios.

4 RESEARCH GOALS, QUESTIONS AND OBJECTIVES

The research goal lies with the facts of designing constructs and models within manageable business rules and constraints. The other goals are described, motivating the following research questions:

- Keeping in view the heterogeneity and multidimensionality of data sources of the ecosystems and embedded ecosystems, how can an integrated framework combine the data sources, with which various IS artefacts needed and articulated are sustainable?
- How is the integrated framework simulated as a knowledge-based IPM with which the life cycle of supply chains is construed for sustainable and successful IPM?

Research Objectives:

a) Design and develop artefacts that describe ontologies for complex heterogeneous data dimensions, for creating knowledge-based structures by using semantic information and rules/axioms and their knowledge. The artefacts need rigor in the integration process. This approach is expected to manage the semantic, schematic, and syntactic and system heterogeneities of *ecosystems* and their domain ontologies and applications in the LSCME and HEEE architectures.

b) Construe the framework and develop it in knowledge-based IPM with multidimensional metadata and meta-knowledge models. The integrated framework is expected to provide new knowledge on the inventory/registry of sustainably manifested management and accounting solutions (business information focus), besides aligning the business operations between organizations.

5 METHODOLOGY

The methodology described in this section, is intended to put rigor on design science and associated different artefacts. The research articles examined in ontology-based data warehousing and mining, their feasibility and applicability in the business organisations have not been the target of ecosystems research in the existing literature to address integration, connectivity and interoperability challenges. In the current research, we put more efforts into descriptions of data linked with a variety of digital supply chain ecosystems and their organizations using IS approach.

5.1 The Relative Advantage of SCM Visual Analytics

Traditional data analysis tools are too rigid and they have been in domain specific, constraining information flow between diverse domains and groups of ecosystem service providers with inactive reporting tools. We explore new visual analytics tools that enable us to explore multiple domains, embedded in LSCME and HEEE, in which hundreds of attributes and volumes of their instances are implanted. New insights can be presented with ease and in real time quickly to interpret interdependent and interconnected data relationships between systems. Visual analytics can envisage the meta-knowledge from metadata structures to explore and exploit the metadata cubes and their data views for interpretation. The knowledge interpreted from metadata views can represent the information from multiple industry domains, usable and or reusable in the IPM contexts. In addition, the tools provide better collaboration among diverse domains (including domain experts) uncovering associations or data relationships from data systems that vary with geography, demography and even across a range of business processes.

With the objective of resolving data heterogeneity and multidimensionality in embedded systems, we propose an integrated framework within a conceptual sustainable digital ecosystem architecture. A DSR approach is adopted to develop an information system guided SCM utilising volumes of empirical data instances (Hevner et al. 2004; Indulska and Recker 2008). Multiple domains in coexistent systems are brought together to explore connections, interpret and evaluate the commonality between diverse systems. Big Data characteristics – conceptualised as attribute dimensions are incorporated in data structuring (Figure 2) and improve the integration processes. To this extent, domain ontologies are built to iterate the structures and integrate them within a data warehouse environment. The Decision Science Information System (DSIS) emerged from the DSR approach is developed for resolving the ecosystem challenges associated with multiple domains, in which the sustainability concerns are manifested. In this context, we venture to implement the DSIS in digital ecosystem architectures such as LSCME and HEEE. The holistic DSIS approach comprises of data modelling, schema selection, and data warehousing and mining, visualization and interpretation artefacts all applied in a single canvass that can facilitate an efficient implementation of ecosystems in decision support systems (DSS). We further outline the multidimensional artefacts within a sustainability policy framework for establishing the connectivity and its interaction among multiple systems (Burke 2013). Besides, analytical tools are proposed for elucidating the connectivity among embedded digital ecosystems (within HEEE and LSCME architectures), emphasizing the data and visual analytics with a quest to extract business intelligence (BI) and its value in terms of supply chain alignments and their knowledge.

To particularize, the activities of DSR facilitate the development of IS guided SCM and explore the interconnectivity in between embedded ecosystems as pictorially explained in Figures 3a and 3b. The research outcomes deliverable to ecosystem service providers are explained in the following sections. Creswell (2014) provides in-depth literature on social science research methodologies, illustrating several quantitative and qualitative approaches. An observational research approach is pursued with qualitative and quantitative interpretation with analysis of secondary data observations acquired for integrated projects, from industry experiences, including the existing literature surveys (Nimmagadda and Rudra 2017). The characteristics related to Big Data tools are consolidated with entities and dimensions of selected ecosystem architectures with various artefacts of DSIS, making the framework generic. The DSIS has diversified scopes, and more inclusive to accommodate multiple ecosystems and their characteristics (Figure 2).

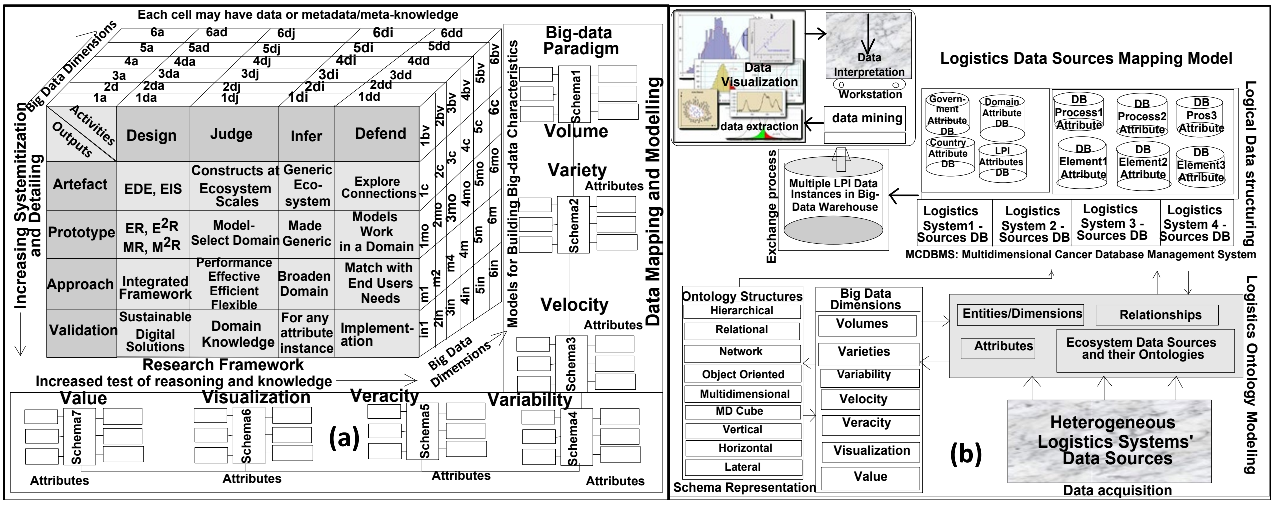

Figure 3: (a) Big Data guided Design Science IS Development (b) A generalized methodological framework (Research Objectives 1 and 2)

Warehouse modelling, which can integrate domain ontologies of LSCME and HEEE composited domains, can also intelligently store metadata in sustainable multidimensional repositories. We have summarized key features of artefacts:

a) Design and develop IS artefacts that describe ontologies for complex heterogeneous data dimensions and their data instances, with interconnected ecosystems in DSIS articulations.

b) Address the semantic, schematic, and syntactic and system heterogeneities of HEEE and LSCMS domain architectures.

c) Use and reuse of constructs and models in various ecosystem scenarios for sustainable interoperability, data science and visual analytics.

5.2 The Current Research in Business Information System Perspectives

Induction of design science within research framework articulation with artefacts deduced from IS/IT concepts and tools can judge the SCM in multiple industry contexts (Viswanadham and Samvedi 2013). In particular, the multiple domains and systems related to LSCME and HEEE and their attributes need knowledge-based human insights and performance in their interpretation. In the context of ecosystems, the design knowledge of artefacts must match and reflect with explicit facts of embeddedness and connectivity between human, environment and economic ecosystems that can impact the LSCME architecture so as to generate and deliver sustainable quality ecosystem services. In other words, the knowledge-based artefacts can be made sustainable with the assimilation of connectivity and embeddedness existing in between systems.

Meticulous analysis of sustainability challenges, how they can be manifested in business information systems in their data hierarchies is the research that could be of enormous interest to scientists and business policymakers (Nimmagadda et al. 2018). The business analysts whose purpose is to strategize information systems in integrated projects with innovative artefact designs seek new information solutions in the form of high performance computing data warehouse repositories that can deliver just-in-time quality ecosystem services. Making business alliances and bridging the communications gaps between industries, especially in a constrained IPM scenarios are ambitious research goals (Miller 2015). The multidimensional warehouse repository is an inventory of ecosystem assets that can store the attributes and resources' data instances, visually predict and provide quality information needed by managers of ecosystem providers. In this context, the LSCME and HEEE are simulated architectures of DSIS with digital replication of sustainability manifested management and accounting, not only for reporting but for decision support analysis. The registry or inventory of the assets of existing ecosystems, their attributes and resources (in a sustainability scenario) are analysed to forecast and provide quality data and information to the managers and policymakers of both LSCME and HEEE ecosystem service providers.

Data interpretation is one of the cognitive artefacts of the DSIS framework (Nimmagadda and Rudra 2017). The major challenge is the interpretation of connectivity between systems through analysis of data patterns between attribute instances of similar and or dissimilar domains. However, visualization can explicitly envisage the hidden knowledge from data patterns to add depth of information in the form of new interpretable knowledge. The contextual-domain modelling and attribute data-modelling, schema design, data warehouse and mining, data visualization and interpretation are various aspects of DSIS framework as described in Figure 3a. Big data features as illustrated in Figure 3b are incorporated within DSIS framework, keeping in view, it is implementable as per DSR guidelines and evaluable utility properties (Venable et al. 2016). Big data collection covers both longitudinal (temporal) and lateral (geographic) design aspects. The data visualisation is one of the packages of innovative artefacts of Big Data guided DSIS, aiming at:

1. Presenting the business scenarios in unified metadata views.
2. Slicing and dicing of warehoused metadata cubes in spatial-temporal attribute dimensions.
3. Interpretation of visual data and map trends in new knowledge domains.
4. Adding values to digital business ecosystem products and services.

6 RESULTS AND DISCUSSIONS

Logistics and Supply Chain Management System (LSCME): We implement data structures or artefacts developed for supply chains in the IPM, as channelled by LSCME with DSR guidelines (Vaishnavi and Kuechler 2007). The data structures demonstrating the connectivity among elements and processes of the LSCME are relevant to multiple industry IPM scenarios and business applications. In the context of LSCME, the businesses, their functions, and activities are explained in the form of an IPM life cycle, demonstrating how the resources can be optimised at different phases of the IPM that include development and implementation. Visual analytics is meant for representing bubble plots of ecosystem data views with periodic and geographic attribute dimensions. The dimensions of the framework are described in Figures 4a and 4b to make connectivity through a star schema model. The geographic and periodic attribute dimensions are expected to play a big role in both applications.

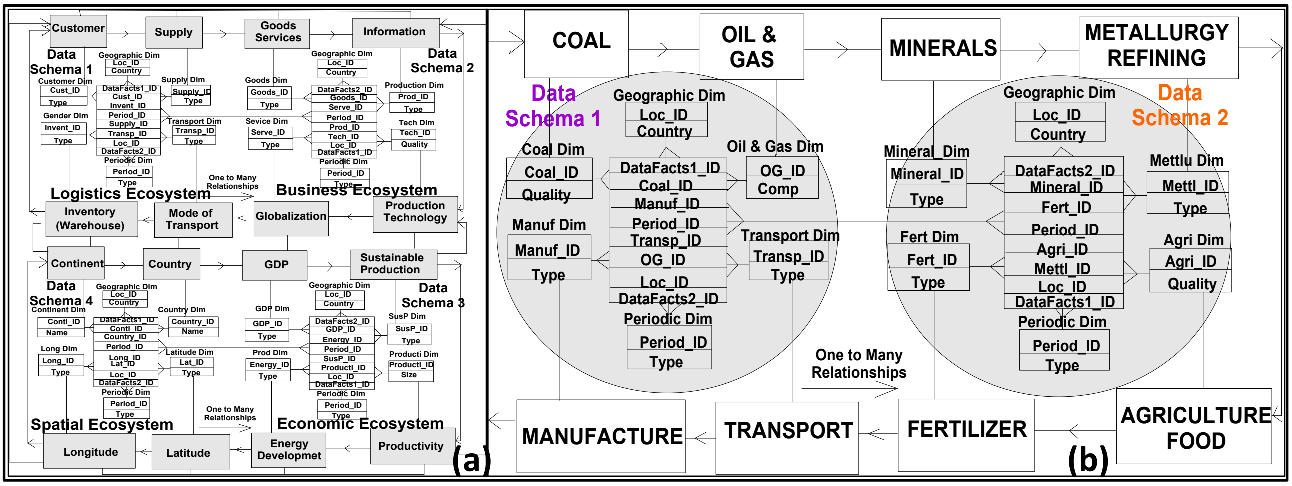

Figure 4: (a) Supply Chain Management - Business Life Cycle – Integrated Project Management (IPM) perspective (b) Ecosystems connectivity through data structures (Research Objective 1)

Establishing the connectivity among various components of HEEE through Spatial Data Science: It is an architecture development scenario, in which human, environment and economic ecosystems are brought together to interpret their connectivity. Diverse data views, in the form of the map, plot and other graphic illustrations are used for evaluating meta-models attributed by volume and variety attribute cubes (Pujari 2001). By making use of an acceptable alliance between coexistent systems and businesses, immense value is added including, systems' behavioural patterns within broader contexts of HEEE, a nested architecture needed for LSCME. The added spatial dimensions are described for aligning the data from concurrent human, environment, economic ecosystems preparing unified data structures. The fine-grained data structures can adhere to benchmarks set and facilitate refining the connectivity process between systems through spatial attributes. Various fine-grained data views are extracted for interpreting the knowledge of digital ecosystems in Big Data scales. As shown in Figure 5a, the cuboid data structures demonstrate the connectivity among elements and processes of the *LSCME* relevant to an integrated project management (IPM) scenario and performance of DSIS in the application development. In the context of IPM, the businesses involved in the form of a business life cycle (Figure 5) demonstrate how the resources can be optimized at different phases of the project.

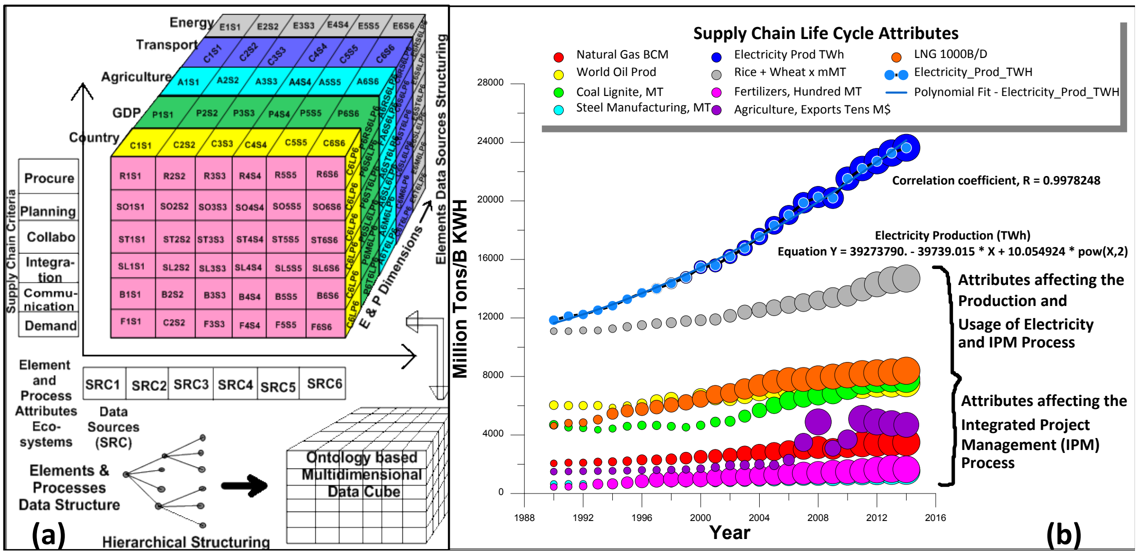

Figure 5: (a) Cuboid structure and (b) supply chain life cycle (Research Objective 2)

Visual analytics carried out using bubble plots in periodic and geographic dimensions has brought out the following research outcomes:

1. The connectivity is established among various components of HEEE through Spatial Data Science: The architectural views of HEEE make effective alliances between coexistent systems. The data views have immense value in understanding the systems and their behaviour within the broader context of design and development of the DSIS framework.
2. The significance of the spatial ecosystem is narrated within the coexistent LSCME architecture guided by the DSIS framework. The application development scenarios of IPM that need connections from multiple industries through meta-knowledge models and graphic analytics are discussed in Figure 5b.

7 SIGNIFICANCE, CONTRIBUTION AND RESEARCH AUDIENCE

Design science is an IT design research articulation; in the contexts of SCM, design knowledge has huge implication in IPM scenarios and related applications. Ecosystem service providers in industry contexts, data analysts and scientists, design science researchers, supply chain managers are beneficiaries of the multidisciplinary research. The knowledge-based DSIS framework discussed in Figures 3a and 3b and implementation illustrated in Figures 4-6 are specific contributions in the development of IS guided SCM and its related LSCME and HEEE. The current research has significance to ecosystem service providers, academics, domain experts and researchers, data analysts and data management personnel. Innovative research problem solutions have importance for investigating the ecosystems' resources in multiple domains. There is a demand for structured data and quality information for solving the sustainability challenges in the IPM contexts. Keeping in view the complexity, heterogeneity, and multidimensionality involved in LSCME and HEEE architectures, a new research direction is considered in data engineering and industry implementations. Spatial data structuring appears playing a vital role in LSCME and HEEE application domains and their data science in industry perspectives. The inventory/registry or multidimensional warehouse repository is intended to be implemented in industry situations through academia-industry alliance programs.

We make an effort to use the rules of geography in the supply chain ecosystems that can regulate the IPM process, in which multiple industries are involved. Supply chains in industry depend on the connectivity between diverse domains at various geographic attribute dimensions and their instances, such as coordinate data and their linked supply chain attribute instances. As per Tobler's First Law of Geography, every attribute and its instance within supply chains of multiple industries is related to attribute instances of data sources of HEEE and LCSME, in which near attributes are more related than distant attributes (Dovers et al. 2001). The spatial attribute instances may impact the interaction between attribute dimensions in the form of *delay* attribute, depending upon the nearness and farness of attributes and their descriptions in the geo-space. In addition, the spatial relationships construed in the logistics and supply chain framework affect the time and cost factors set for IPM scenarios. The resistance observed due to the distance between attribute dimensions may cause an increase in costs, instigating the distance decay effect. We intend to analyse the phenomena in the supply chain ecosystems, weighing the relationships and or interactions between various attribute dimensions of the IPM, envisaged in multiple industry environments as demonstrated in Figures 6a and 6b.

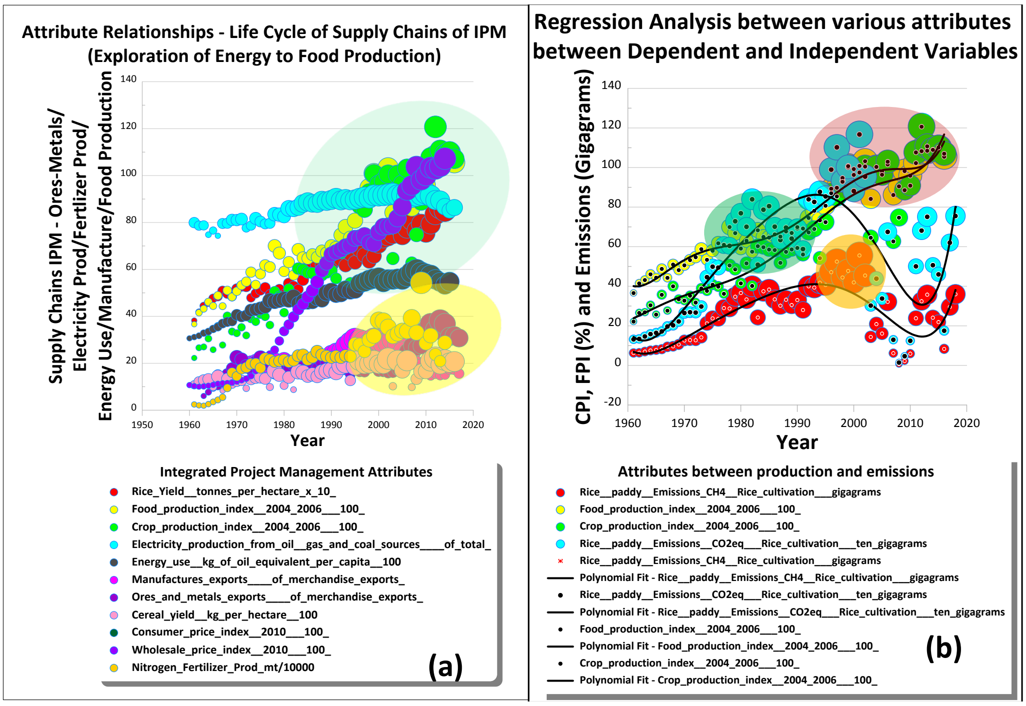

Figure 6: Bubble plot visualization, showing the connectivity between attributes of supply chains depicting (a) attribute relationships and (b) regression analysis (Research Objective 2)

Several attribute dimensions involved in the IPM in multiple industry scenarios are compared. The complexity is analysed through the bubble plots drawn for connected attribute dimensions of energy, mineral and mining, manufacturing, fertilizer, agriculture and food industries. As described in Figure 6, Wholesale Prices Index (WPI) is used to measure the average change in price for a sale of goods in bulk quantity generated by IPM with valued interconnected supply chains. WPI is a measure of leveraging the commodity prices at selected levels before the product reaches the consumer. WPI is the first level of measure where the first price increase of goods is observed. It is restricted to goods only covered under WPI, primarily fuel, power, and manufacturing products including fertilizers, agricultural and food produces. The attributes and their instances are very close to each other, as represented in envelopes in Figures 6a and 6b, demonstrating adherence to the Tobler rule of geography. The findings and their discussions answer the purpose and the contributions of the research study.

8 CONCLUSIONS AND RECOMMENDATIONS

The conclusions state the main claim of the research. The constructs, models and methods that make up the DSIS are intended to evaluate utility properties with technology rules and constraints. The dimensions, attribute strengths and fact instances of LSCME and HEEE are sensitive to the connectivity and boundaries of multiple ecosystems, appear positively constructive to sustainable knowledge needed in the IPM. The use, reuse and effectiveness of constructs, models, methods and knowledge are typical in evaluating the utility properties. Data quality, use, ease of use, interoperability and effectiveness are the other evaluation properties of the constructs and models, analyzed robustly to make the DSIS more holistic and applicable in wider domains and contexts of IPM. The decisions made based on the metadata and data views deduced from DSIS in IPM project contexts may help improved investment opportunities. The influence of the economic trends of the integrated project in multiple industry scenarios is valued to make the IPM successful and cost effective venture.

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