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On Modelling Big Data Guided Supply Chains in Knowledge-Base Geographic Information Systems

Shastri L Nimmagadda[a]*, Torsten Reiners[b] and Lincoln C Wood[c]

[a,b]*School of Management, Curtin University, Perth, WA, Australia*

[c]*Department of Management, Otago University, Dunedin, New Zealand,*

Abstract

We examine the existing goals of business- and geographic - information systems and their influence on logistics and supply chain management systems. Modelling supply chain management systems is held back because of lack of consistent and poorly aligned data with supply chain elements and processes. The issues constraining the decision-making process limit the connectivity between supply chains and geographically controlled database systems. The heterogeneous and unstructured data are added challenges to connectivity and integration processes. The research focus is on analysing the data heterogeneity and multidimensionality relevant to supply chain systems and geographically controlled databases. In pursuance of the challenges, a unified methodological framework is designed with data structuring, data warehousing and mining, visualization and interpretation artefacts to support connectivity and integration process. Multidimensional ontologies, ecosystem conceptualization and Big Data novelty are added motivations, facilitating the relationships between events of supply chain operations. The models construed for optimizing the resources are analysed in terms of effectiveness of the integrated framework articulations in global supply chains that obey laws of geography. The integrated articulations analysed with laws of geography can affect the operational costs, sure for better with reduced lead times and enhanced stock management.

Keywords: Supply Chain Management; Project Management; Laws of Geography; Domain Ontologies; Data Mining

1. Introduction

The logistics and supply chain management systems are analogous to any other information systems [2, 6, 13], and the motivation of research lies with facts of the existence of large volumes and variety of data and information. The concept of an ecosystem composited with multiple supply chain systems is presented. The events of elements and processes of supply chains occurred at various geographies constitute the ecosystem scenarios. The business activities

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: shastri.nimmagadda@curtin.edu.au

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integrated within ecosystem scenarios are envisioned to make supply chains effective at optimized costs. The current research paradigm offers a new problem solution in the optimization of resources, especially when supply chain events need alignments from multiple industry operations through multiple dimensions of their data sources. Volumes and variety of Big Data do exist in spatially controlled supply chains and their dimension attributes [2, 19]. The data sources, which are diverse in industry situations, with different geographic attributes are considered in dimensional modelling. Hundreds of data attribute dimensions are identified from elements and processes and their fact instances varying with periodic and geographic dimensions. The basic elements of the supply chain systems are demand management, communication, integration and collaboration [6, 12]. Strategic, demand and supply planning, procurement, manufacturing, warehousing, order fulfilment and transportation are vital processes of the supply chain management. In addition, movement of required materials, keeping stocks of right materials, timely delivery of materials and supply of the finished goods to the consumers are added value events in the development of the supply chain systems. In the current context, we describe each element and process of the supply chain ecosystem (as defined in a 3D view in Fig.1) with the number of entities and or dimensions, data attributes and with volumes of fact instances in between supply chain events. Considering the scale and magnitude of the databases that interlink diverse systems, we need better tools and technologies. In pursuance of resolving data explosion challenges, Big Data technologies may be right choice for multiple tasks of logistics management systems.

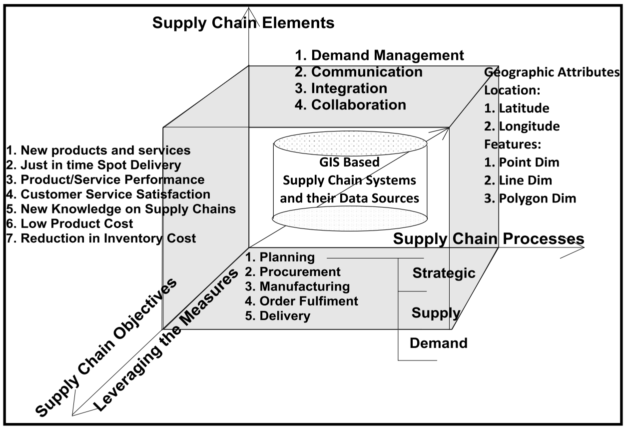

Fig.1: 3D View of supply chain elements and processes

As an example, coal – oil - gas – minerals – metals - metallurgy- manufacturing – fertilizers – agriculture industry scenarios are described in a hierarchy, from energy production to its usage, exploiting the Big Data opportunities through an integrated supply chain framework [2, 12]. The data and information flow requirements in supply chains that influence the framework are evaluated for their achievable performance at reduced operational costs, improved stock management with feasible product and service qualities. We assess the need of data in multiple domains and systems required in the unification process. The volumes and variety of data related to supply chains are analyzed and how they can be aligned in a unified framework to depict and make effective business alignments. In addition, we are of the opinion that the laws of geography [15, 26] can facilitate in understanding the connectivity between spatial dimensions of supply chain systems and their global events. The spatial attribute dimensions (as described in the geographic attribute list in Fig. 1) control the logistics systems globally, monitoring the multidimensionality of aligned data sources [23].

We organize the paper with various sections and sub-sections, describing the issues, challenges and motivation of the current study in Section 2, modelling the constructs with various data entities and dimensions in Sections 3 and 4. Keeping in view the global demand of the current competitive business environment, we introduce an "ecosystem" concept in the supply chain system scenarios. An integrated methodological framework is articulated in Section 5 in which the constructs and model artefacts are accommodated, simulating an ecosystem in the computing environment. How best the attributes of supply chains can obey the laws of geography, are examined in the integrated project management. Data mining, visualization and interpretation, are other artefacts discussed in Section 6, extracting new knowledge of supply chain ecosystem and adding the values to the integrated project management.

1.1. *Complying Laws of Geography and Easing the complexity of supply chain ecosystems*

We intend to apply the rules of geography to supply chain ecosystems in an integrated project management scenario in which multiple industries have different roles to play. Supply chains in industry perspective depend on the connectivity between different domains, in particular at various geographic dimensions, such as coordinate data and their controlled, rather linked supply chain attribute events. We believe due to Tobler's First Law of Geography [9], for every attribute and its instance within domains of supply chains is related to every other attribute instances of other domains/systems, but near attributes are more connected than distant attribute dimensions. Accordingly, the spatial dimensions can impact the global supply chain attribute dimensions and their interpolations as per Gaussian regressions, governed by covariance. The spatial distance may have a bearing on the interaction between attribute dimensions in the form of a delay, depending upon the nearness and farness of attributes and their descriptions in the space. In addition, the spatial relationships can control the time and cost factor analysis attributes, as construed in the logistics and supply chain framework. The noncompliance observed due to the distance between attribute dimensions may have causative effects on costs, instigating the distance decay effect [13, 26]. We intend to analyze the phenomena in the supply chain ecosystem scenarios, in which the interactions between various attribute dimensions are weighed in the integrated project management environment.

To comprehend the economic potential of spatially distributed supply chains and their information, we realize the development of a conceptual framework as in [19]. In the digital economy era, as per the 2nd law of geography, we relate the current research with new research frontiers. Every attribute dimension and its connectivity with other attribute dimensions are emphasized with increased economic activity and its value in spatially enabled Big Data tools and technologies. The significance of geographic dimension, connecting to economic values of supply chains has a gaining momentum, especially providing quality business ecosystem services in the era of the Internet of Things (IoT), easing the complexity of business alignments through data associations between supply chains. The analysis of two laws of geography is intended using various line and scalar and bubble plots drawn between various attribute dimensions, exploring the connectivity between attributes, ensuring connectable attribute events are interpretable in terms of spatial dimensions.

The authors take advantage of the spatial-temporal dimensions in offering sustainable integrated project management solutions in the current research. The spatial dimension defined within the first law of the geography has a relationship with the digitization of attributable dimensions of an economic ecosystem, as envisaged in the contexts of integrated project management. In addition to the spatial dimension, the periodic attribute dimension can connect the laws of geography, which can further enlighten the sustainability of participating attribute dimensions in making feasible supply chain ecosystems, which may be termed as 3rd law of geography [9, 15]. The quantities and prices are managed in a manner to fulfil the demand and supply throughout the supply chain life cycle.

The rest of the paper is organized as follows. Issues, challenges and the motivation of research are described in Section 2. The research objectives and significance are discussed in Section 3. An integrated framework is proposed in Section 4. The analysis and discussions are given in Section 5. The conclusions and recommendations are given in Section 6, followed by the future scope and vision in Section 7.

2. Issues, Challenges and Motivation

Various issues and challenges associated with data management of integrated project management are discussed [3, 4]. The data are gathered from various entities of project timelines and schedules, budgetary allocations and distribution of raw materials at unit levels, the people skills and right people in right place and communication skills. Integration, product conceptualization and implementation of integrated project outcomes are major challenges. Also, volumes and variety of heterogeneous and multidimensional databases, the storage and retrieval of Big Data information are other critical factors. Minimizing the overhead costs and optimizing the product or service qualities (that can increase the maximization) are other challenges. The most common issues are poorly connected, geographically dispersed supply chains, use of unsuitable tools in the job, overly ordered resources, unnecessarily delays in search of project resources and excessive time spent on project meetings [12, 13, 18]. In addition, analyzing the challenges of data qualities and data loads in high-speed computing devices are other issues. Big Data tools [1, 7] motivate us in modelling data constructs that link various supply chains and their integration in the integrated methodological framework. Fig. 2 is a description of structured entities or dimensions, interpreted from the elements and processes of the supply chain system. For conceptualizing new products and services, the Big Data innovation is examined that led us optimizing the supply chains at reduced operational costs and inventories. As described in Fig.2, (D, COM, I, COL) are elements and (PL, PR, M, WA, T, O) are processes of supply chain systems. Inherently, they are interconnected with elements (GDP, GCOMP, GIM, GCOLWA, GTR, GO) of geographic information systems.

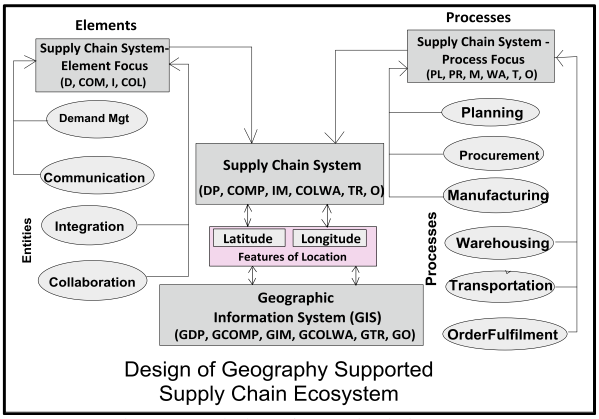

Fig. 2: Description of a supply chain system

3. Research Objectives and Significance

The research objectives are (1) to build constructs and models (2) to simulate a supply chain ecosystem in the form of an integrated framework, articulating the constructs and models (3) to implement the framework in the integrated project management scenarios. These objectives are laid keeping in view the significance of laws of geography for setting geographic information systems and establishing their role in the logistics and supply chain management systems. We describe the significance of multiple industry involvement in the integrated project management in which multiple chains of events [10] may be vital in modelling knowledge-based information systems:

- Projects are undertaken with the means of development and economic upliftment with an improvement in the quality of life. Integrated projects offer building blocks in generating additional capital and reduced delays in project implementation, and overhead costs are kept to a minimum.
- Power, steel manufacturing, and petroleum sectors, irrigation, mines and chemicals are interconnected industries with capital intensive, accounting 41.5% of the total current plan outlay in the public sector with power sector amounting 19.8%. Any delays caused in the operations or commissioning of power plants may have an enormous impact on the performance of other industries and production.
- A multitude of complex operations delay the project implementations, the majority of them are due to the inadequate data management systems. Effective management information systems involve decomposition of complex problems into many simple data solutions. Data and information can provide better planning and way forward to interrelated projects. The timely information at geographically located project sites makes a huge difference in terms of project executions.
- Project management functions ensure with systematic execution and at par with project guidelines to plan logically and identify problems quickly and promptly.
- The success of the project management process is measured not only on its effectiveness but on how well the people responsive on schedules and follow-up procedures.
- An appropriately designed data-organization provides an essential framework for efficient project management. For projects being implemented by large multi-unit entities, it is desirable to develop a functional approach with centralized policy formulation and decentralized implementation. The organization design should reflect the vertical and horizontal linkages defining the responsibilities and functions at all managerial levels.
- Timely implementation of the project outcomes is another measure of integrated project success.
- For making the implementation process more effective, it is necessary a detailed level planning, ensuring each activity is planned at each and every managerial level.

3.1. Ecosystems in Supply Chain Scenarios

An ecosystem is regarded as a system in which the associations across reputable systems happen to be conjointly constructive, beneficial and significantly closed [8]. It is the case for an expansive system, described with geographic dimensions in several systems between different countries. A digital ecosystem is a developing phenomenon, in which all the interpreted, conceptualized and contextualized attributes are ontologically described and made unified through multidimensional structuring through various logical schemas. This approach motivates us to develop new Information System (IS) articulations and tools in the logistics and support service contexts. An ecosystem aims at to generate "local to global" opportunities, products or services engendered in chains of activities and occurred in diverse business perspectives. The region exhibits a network of extended networks from the ecosystem. It presents an amicable deal to businesses in the distributed environment, which has a significance on new knowledge building in broader contexts of the supply chain management ecosystem driven framework. An ecosystem by definition is a system, or a group of interconnected elements and processes, formed by the interaction of a community of chains within their environment [19]. The construct modelling and analysis, the description of diverse systems with dissimilar chains of events are the focus of supply chain management ecosystem research. Each ecosystem is a composite identity with an active single ecological entity. Pragmatically, it is a term with millions of data attributes, characterized by volumes of DBs of manifold ecosystems all that stored in one place. Here an ecosystem implies groups of systems, their connectivity and interaction among various chains or activities [9, 10].

3.2. Supply Chain Ontology (SCO) – an Ecosystem Scenario

We discuss a comprehensive framework as given in [22, 20, 26] for different ecosystem scenarios. Large sized Big Data and their characteristics hold definitive relations in connecting multiple systems in ecosystem scenarios. Ontologies as described in [19] conceptualize the framework, articulating Supply Chain Ontologies (SCO). The key criteria are (1) a hierarchical classification of concepts represented as classes, from general to specific; (2) a list of attributes related to each concept and for each class; (3) a set of relationships between classes to link with ontologies in more information-rich ways than implied by the hierarchy, thus promoting the reuse of ontology constructs in various concepts and contexts; and (4) a set of algebraic operators necessary for probing the supply chain data occurrences or instances [6, 12].

We further examine considerable data events occurring through analysis of conceptual models of SCO. Products or services offered by various supply chains are examples of integrated interpretation of data sources in various domain knowledge outcomes. In principle, the periodic and geographic data change the frequencies or occurrence of events associated with supply chains. Ontologies describe conceptualization of the entities in multiple realms, unifying the multifaceted data in a warehouse environment. We draw ER diagrams [19, 22] based on factual data dimensions, attributes and instances, held in company scenarios. We use data instances published in [12, 24] in the dimensional modelling process.

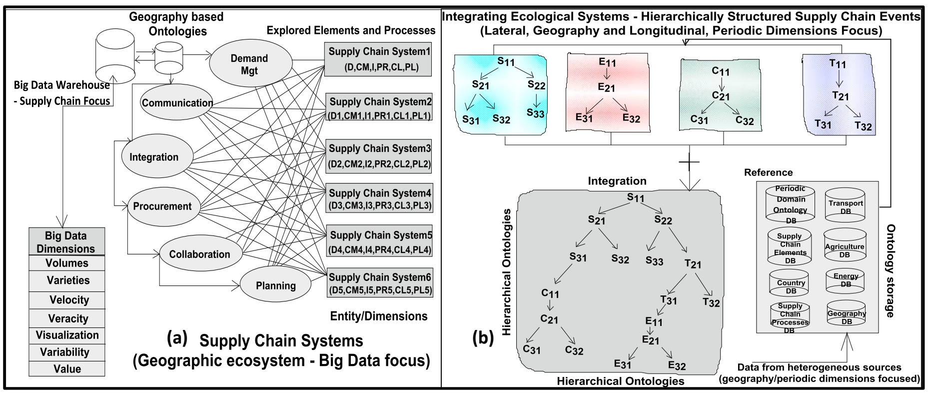

Fig. 3: Geography based multiple supply chains in Big Data focus (a) showing connectivity (b) a hierarchical data structure

The use of constructs and models, based on factual data is the real motivation of current research. Dimension and facts are derived from factual supply chain events occurred in different geographic regions. The star and or snowflake schema are in combinations used to construct a fact constellation schema to support complex and typical applications of supply chain ecosystems. The architecture is fused, because of the fact, it needs to manage multiple fact tables [20, 26], but required for multiple supply chain events' representation and interpretation. It allows sharing of dimension tables amid multiple fact tables, as done in the case of sub-systems' design and analysis using multiple information system scenarios [2]. Similarly, the domain ontologies integrated with the warehouse environment and their simulations are extended to other ecosystems' scenarios.

We describe ontologies for connecting multiple dimensions of data sources of supply chain systems in multiple industry scenarios. While describing ecosystems in supply chain management, we underline the characterization and description of data sources in diverse domains. "Millions of records from thousands of attributes and their instances in a single repository" is termed as a digital ecosystem. In another metaphor, productive or non-productive ecosystem [22] consisting of several systems is itself an information system either supply chain or geographic information system. The information is documented from several operational units, such as exploration and exploitation of coal and oil and gas resources that drive various manufacturing and transporting units of the integrated project that happen in different geographies. For this purpose, several data attribute dimensions of functions and activities are interpreted and documented. Each unit is characterized and operated by one or more supply chains, and each chain has a product or action or service. In a broader context of the ecosystem, the generalization and specialization are interpreted in a hierarchy that describes multiple domains with multiple chains and their linked dimensions, attributes and data instances. In other words, a system whose members are hierarchically associated to each other is further linked to other inherent ecosystem scenarios.

4. An Integrated Framework

The supply chain digital ecosystem framework refers to the formal union and connectivity paradigm among a variety of individual systems through integration of various constructs and models. For the purpose of identifying data relationships, validating them for modelling, various supply chain events are analyzed with ontology descriptions. For example, multidimensional data sources in multiple industries that need to go through the data integration process, are initially conceptualized and contextualized, interpreting hundreds of supply - chain events and attributes geographically. Each chain in a supply chain is emerged based on the interpretation of several multiple conceptual dimensions used in the integration process. While mapping and documenting attribute instances in a warehouse environment, different properties of chains are considered as multiple dimensions, at places conceptualized. We consolidate all supply chain data events that evolved from elements and processes of multiple industry ecosystems and their associated property dimensions into a warehouse environment.

The processes of supply chains are interconnected through various elements, based on their existence and occurrence within the system. In the integrated framework, each chain interpreted in a system inspects for numerous data dimensions of the neighbouring systems and their instances. The attributes in each and individual dimension (of an element or process) are again segregated or categorized for empowering an effective integration process that may even facilitate the data mining process at later stages. It validates the process of denormalization. In the case of supply chain digital ecosystems, we categorize all the elements participating in an ecosystem-integration process in a way the ontology description understands each element's terminologies, including semantics, schematic and syntactic information of attribute dimensions.

As shown in Fig. 4, we focus on designing an integrated framework, keeping in view the current supply chain management challenges. We adopt the star, snowflake and fact constellation schemas for constructing multidimensional logical data models as discussed in [13, 19] and [11, 5, 25]. The warehoused data are outcome of hierarchically organized instances in dissimilar knowledge domains as proposed in [16, 17]. An initial hierarchical structural view described in Fig 3b characterize the relationships among attribute dimensions from diverse domains [14, 21, 22]. Several stages of data modelling are described in Fig. 4, in which the data acquisition, construct design activities including metadata, their mining, visualization and interpretation are detailed. Since the data are from geographic information systems, the Big Data characteristics are integrated within the integrated framework. We intend to focus on fine-grain multidimensional data structural design through hierarchical structuring process. The methodological framework as discussed in Fig. 4 is the description of process of unifying domain ontologies and their associated knowledge in fine-grained metadata. The framework has various stages of data acquisition, processing and interpretation artefacts that needed to arrive at a metadata for new knowledge discovery and interpretation.

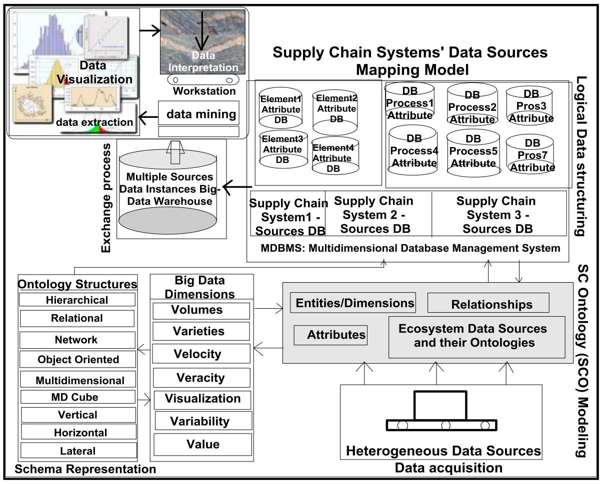

Fig.4: An integrated framework with SCO articulations

To further manage the framework, we compare the ontology descriptions in taxonomic classes, class definitions, and class conceptualizations of relationships interpreted in multiple domains of SCO applications [22]. Business rules and axiom constraints need to be committed during contextual interpretations and detailed conceptualizations. The concept of an ecosystem is beneficial with several multi-disciplinary entities or dimensions' participation through conceptualized relationships in the integration process and throughout symbiotic positive-sum relationships. This fact is corroborated from biology and referred as a self-sustaining system [22, 26]. A similar analogy is applied to a wide and large size logistic and supply chain ecosystem that surrounded by several hundreds of attributes and connected with large areal extents of systems or networks at both local and global scales.

The design of the information system in the integrated project management banks on the individual design of conceptual schemas of various operational units of multiple industries. For sustainable supply chain management, thus to legalize and validate the data sources in multiple contexts, we need to integrate schemas [22] belonging to different operational sub-systems. Intelligent and expert data systems used in [5, 23, 26] support our current research and the proposed logistics and supply chain management framework.

5. Analysis and Discussions

To ease the complexity of supply chain systems in multiple industry scenarios and the integrated businesses, we adopt various concepts from the set theory and linear programming (LP) techniques [20, 22]. We present different dimensions and attributes evolved from elements and processes in the supply chain digital ecosystem framework. When businesses involved with multiple industries, the project managers use their resources more judiciously, with minimum operational costs and maximum profits. The problem is to optimize the resources using integrated business solutions [3, 4]. Though it is beyond the scope of the current research, multidimensional linear programming (MLP) approach appears to be an optimum solution for managing the interdependent multiple activities within available budgetary resources. Alternatively, available resources are allocated in an optimum manner satisfying the laws of geography and policies of supply and demand of the company's products. The approach plans for various activities that referred in a line of action from amongst several alternatives for cost minimization or profit maximization [9], as focused on the problem of allocation, assignment and transportation. We use the integrated framework to generate metadata cubes and data views through slicing and dicing [25]. We link different elements of ecosystems through cuboid structures as discussed in various logistics scenarios in [12]. We explore the integrated project management and the connectivity through SCO approach as described in Fig. 5. Multiple dimensions are interpreted from various operational units of multiple industries in a way to design star-schemas as described in Fig. 5. As shown in Fig. 5, supply chains, their connectivity and business life cycle are interpreted through multidimensional attributes connecting data schema 1 and data schema 2 enabling to explore the inherent and unknown connections between multiple industries. The industries chosen in the current analysis are described in the following sections.

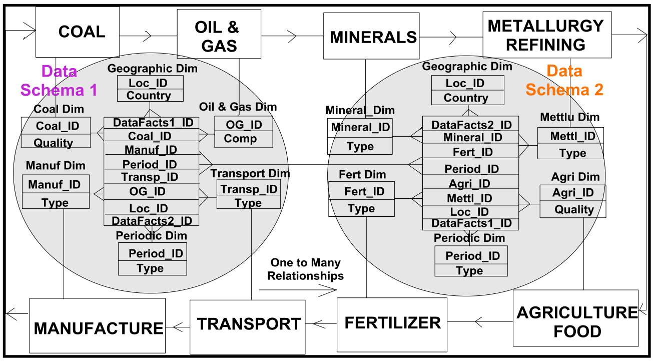

Fig. 5: Supply Chain Management in a Business Life Cycle – data management perspective

5.1. *Oil & Gas and Coal (OGC) facilitating the Manufacturing, Fertilizers and Agriculture Industries*

The oil, gas and coal exploration and exploitation need attention especially with the projects associated with manufacturing, power, metals and metallurgy, fertilizer and agriculture industries. The energy from oil and gas and coal drive the heavy industrial operations. Manufacturing implies production of components for use or sale using the existing labour, machines and tools. The finished products on a large scale for retailing or selling to end users in the integrated business - industrial informatics scenario. In the context of energy production scenario, how the oil and gas and coal resources have an impact on manufacturing, mineral and metallurgy including their impacts on related industries such as fertilizers and agriculture industries, such that more production is achieved with reduced costs. In many countries, fertilizer and agriculture industries are heavily dependent on uninterrupted energy supplies. Data attributes are deduced from these interlinked industries for multidimensional modelling.

5.2. *Power and Energy Industries coordinating the Manufacturing Industry*

The pump sets, controllers, engines, generators are examples of tools of power and energy industries. The data dimensions and attributes are deduced for modelling in multidimensional schemas. In the case of power generation scenario, power plants, electric power transmission, electricity distribution and retailing of electricity are various sub-type dimensions incorporated in the data modelling process.

5.3. *Minerals, Metals and Metallurgy facilitating the Manufacturing Industry*

Raw materials, planning and in-time supply of iron ore materials are critical in the manufacturing process. Base metals are part of components needed for metallic and metallurgical processes. Exploration of the minerals facilitates the interconnectivity between mining, metallurgy and manufacturing operations. Also, uninterrupted supply of oil, coal and natural gas is ensured to long-term operations in power and energy industries. Collaborative research in developing innovative processes or products formulates the connectivity of multiple industry operations in the integrated project management. The procurement, construction, Quality Control (QC) of material and equipment, production, raw material preparation, process metallurgy, material manufacturing and applications are entities and various dimensions are attributed for modelling.

5.4. *Fertilizer Industry facilitating the Agriculture Industry*

The liquefied natural gas (LNG) based urea, potassium and phosphates are essential for agricultural production. The fertilizer industry relies on the uninterrupted supply of liquefied natural gas (LNG). The exploration and exploitation of natural gas indirectly enhance the promotion of the fertilizer and agriculture industries for achieving optimum targets. During project implementation, the timely requirement of physical possession of the land, allocation of scarce materials, equipment, manpower, and transportation is examined. For testing and evaluating the integrated supply chain framework (Fig. 4), several existing secondary data sources are considered. The complete business life cycle as shown in Fig. 6, is demonstrated, describing the data of elements and processes of supply chain events from exploration and production of oil, gas, coal, energy, to the utilization in agriculture and food industries. A steep rise in power generation is interpreted with the corresponding increase in the agricultural sector, but the rise in food production is not observed, which could be due to misappropriation of resources at various supply chains.

5.4. *Laws of Geography - Spatial Analysis of Supply Chains*

We have taken advantage of laws of geography to establish the connectivity between logistics and supply chain events and the spatial-temporal dimensions in the current contexts. We choose cuboid metadata to generate several data views as slices and dices, presented in Fig. 6a. Unions and joins [22] are made among data views of selected elements and processes and their data slices for visualization and interpretation. We establish the relationships between various attributes in new knowledge domains and systems, presenting near attributes are more related than distant attributes as shown in Fig. 6b, obeying the first law of geography. Bubble plots can present different alignments of dependent or independent variables of supply chain measure attributes in different scalar descriptions. We present the results in 2D bubble plots, in which the diameter of each bubble varies in size, with representation of additional dimensions in spatially varying logistics and supply chain management data. The connectivity further reiterates with the increased economic activity and its occurrences in spatially enabled global scenarios as shown in a bubble plot in Fig. 6b, the bubbles in certain envelopes are closely connected than certain bubbles distantly pulled apart. It postulates that in the integrated project development environment, the supply chain life cycle settles with facts, where quantities supplied as shown in Fig. 6c, the demands fulfilled from energy to food generation, implying that in a competitive market, the quantities demanded are equal to the quantities supplied thereby interpreting an increased economic activity from sustainable supply chains, obeying laws of geography as exhibited in encircled envelopes in Figs. 6b and 6c.

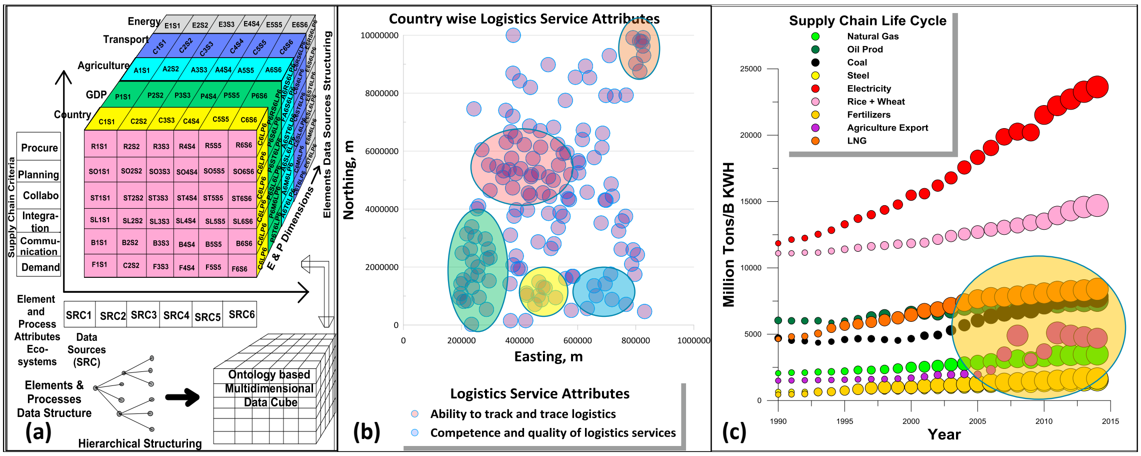

Fig. 6: Metadata with (a) cuboid data structure (b) geographic attribute slice (c) bubble plot view of supply chain attribute events

6. Conclusions and Recommendations

Based on the ontology constructs and models, the articulated the framework and analysis of results, we made the following conclusions:

1. Big data dimensions associated with the integrated SCO (domain ontologies) framework enable us to connect various events of the supply chains and logistics globally, concomitant to the integrated project management.
2. The integrated approach describes ways to accomplish cost reduction, process enhancement, faster implementation and new product development.
3. The methodology comprising of *define, measure, analyse, improve, control* offers a structured solution and a disciplined approach for solving problems associated with multiple industry business events.
4. Big data tools are made good use of examining the connectivity and interaction among the elements and processes of the supply chain ecosystems with respect to geographic information systems.
5. The ecosystem framework can generate economic values among industries associated with the supply chain and geographic information systems.

7. The future Scope and Vision

The knowledge of the ecosystems is an emerging phenomenon in many applications. The supply chain ecosystems have an opportunity to link with the human, environment and economic systems and integrate them into other interrelated ecosystem scenarios. The new science and technology initiatives are encouraging us to study and analyse overall global ecological systems. Big Data associated ecosystems are often spatial-temporal in global scale. These dimensions leverage the data sources of other linked ecological systems. Besides, they are unstructured, heterogeneous and multidimensional, distributed on a continental scale, providing new opportunities in the geographic information sciences' research.

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