Improving Spatial Data Supply Chains

Learnings from the Manufacturing Industry

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Abstract **- Government spatial data holdings are the basis of many Geographic Information System applications and users have come to depend on this information for reliable evidence-based decision making. However, many spatial data supply chains, particularly those that span multiple organisations and different levels of government, are not effective and users are having to make do with out-of-date and incomplete information. The manufacturing industry has a long history in supply chain analytics and well established models. This paper discusses five traits that have generated production efficiencies in manufacturing and can be applied to effectively produce spatial data that is *fit for purpose* in the user's context. The successful supply chain traits are: a) formalized extended supply chain strategies; b) information metrics and measures; c) closed loops; d) traceability; and e) the ability to effectively communicate quality and purpose to end-users. A supply chain framework incorporating these traits is proposed for extended networks.**

Keywords-Spatial Data; Supply Chain Management; Strategy; Traceability; Fit for Purpose.

I. INTRODUCTION

Supply Chain Management (SCM) is a field of study that has evolved since the 1980's [1], principally in the manufacturing industry. SCM encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and logistical management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service and technology providers, and customers [2].

Incremental innovations and best practice SCM solutions have evolved over time and there are opportunities for the spatial sciences to take advantage of these developments to address some of the deficiencies in extended (nationwide and cross-agency) spatial data supply chains that involve multiple suppliers, producers and consumers. Five areas where the spatial industry can improve performance are:

1) *Channel partners collectively adopt a* Supply Chain Strategy. *The strategy needs to be cognisant of the business models of each supply chain participant as well as the end-user in the extended supply chain. Currently, spatial data management often operates in a business vacuum and is not tied to the needs of end-users in cross-agency supply/demand systems. A supply chain strategy is critical to delivering value to the end-user, reducing costs and fostering innovation in extended supply chains.*

2) *Use of* Information Metrics and Measures *for capacity planning, financial management, just-in-time delivery and end-user satisfaction. These metrics and measures are implemented within a SCM system to deliver on the supply chain strategy. SCM systems seamlessly integrate functions and provide communication between organisations participating in the entire spatial data supply chain.*

3) *Making the most out of* Closed Loop Supply Chains *(information backhauls) as a method for strategically sourcing spatial data. Capturing reverse material flows either through process automation or crowdsourcing has potential to enable real-time spatial data supply chains.*

4) *Formalise* **s***upply chain* traceability *through regulations and standards to track and control spatial data, and ensure products are produced responsibly and to the required quality. From a business perspective it is about understanding who is using data and how; and from a consumer perspective it is about being able to understand the risks inherent in data for decision making.*

5) *Being able to* communicate 'Fit for Purpose' *to end-users so they have the knowledge about product suitability. The manufacturing industry does this well through easily understood rating systems, while, the spatial industry relies on a user's understanding of complex metadata.*

This paper discusses these five manufacturing supply characteristics (Sections 3 to 7) in terms of their effectiveness and applicability to spatial data supply chains. Prior to this, Section 2 presents the functional concepts with the objective providing a common understanding of supply chain terminology. This is important as one of the limiting factors in establishing supply chain theory in the spatial domain is the lack of a controlled vocabulary for ontology development. Finally, Section 8 introduces the high-level Supply Chain Framework, which adopts the lessons learned from the manufacturing industry and is being used to generate an ontology to understand the interrelationships between supply chain domains.

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II. SUPPLY CHAIN FUNDAMENTALS

The term supply chain stems from the manufacturing industry. It is gaining common usage across the wider spatial sector where it is used to describe the flow of raw spatial data through to the end-user as a product. However, the supply chain concepts, terminology and theory that are ingrained in manufacturing [3], are not entrenched in the acquisition and management of spatial information and its delivery as a product, particularly in extended supply chains, such as cross-agency networks and National Spatial Data Infrastructures.

A simplified network is illustrated in Figure 1 to explain the concepts, terms and relationships between organisations (supply chain nodes) that need to work in synergy to store, process and create component parts of a product that are progressively aggregated and combined to deliver a product or service to an end-user further along the supply chain. The nodes represent locations where value-added operations occur and include supplier, producer and distributor nodes, as well as mixed nodes. Arrows represent the linear flow of spatial data and customer information. These are referred to as supply chain links. Flows between the nodes are two-way and consist of material flows (data) and information flows (customer requirements and product feedback). There are typically several supplier and customer tiers (1…*n*). These tiers are illustrated in Figure 1.

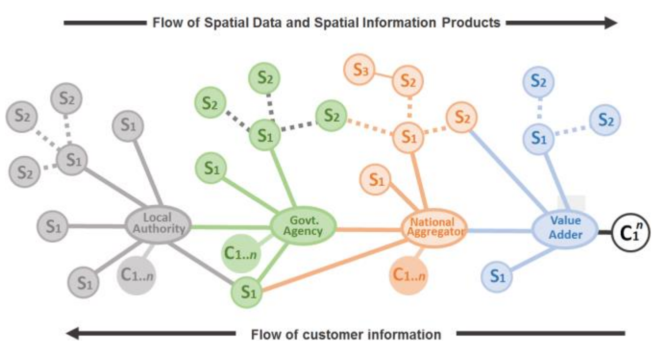

Figure 1. An example of a linear spatial data supply chain that is characterised by nodes and links; data flows and information flows.

Supply chains integrate supply (push production) and demand (pull production) management within and across organisations. *Push* production is based on forecast demand and *pull* production is based on actual or consumed demand.

In the spatial industry, the *push* approach is a business response to anticipated customer demands, long range forecasts or forecasting based on previous sales (downloads and/or views) and the maturation of the market with respect to geospatial understanding.

In contrast, the pull approach is typically a query driven approach. End-users require knowledge about location to answer a question or to visualize patterns and complex relationships so that they can make an informed decision. This is the subject of rapid spatial analytics.

This paper focusses on push supply chains, drawing on comparisons with the manufacturing industry to reduce production costs and attain operational excellence.

Push supply chains are generally non-linear [4] and there are few models that capture the web of multiple networks and relationships required to understand spatial data lineage from its initial capture through to its transformation and delivery as a product or knowledge service further downstream.

The inherent complexity and convoluted nature of digital supply chains is highlighted in a recent study into Australian geocoded addressing [5]. Geocoded addresses (verified or otherwise) are pushed (or dragged) along various pathways from one supply chain participant to another (Figure 2). While an authoritative 'primary' pathway exists for address data, many government departments, hospitals, education institutions and businesses collect address information directly from home occupiers using online forms or over the counter. These address data sets may enter the primary supply chain at any point where residual value is deemed to be recyclable. However, data integration is essentially manual and few data sets incorporate verification processes. Therefore, time delays and the potential for human error may compromise the value of this data to the consumer.

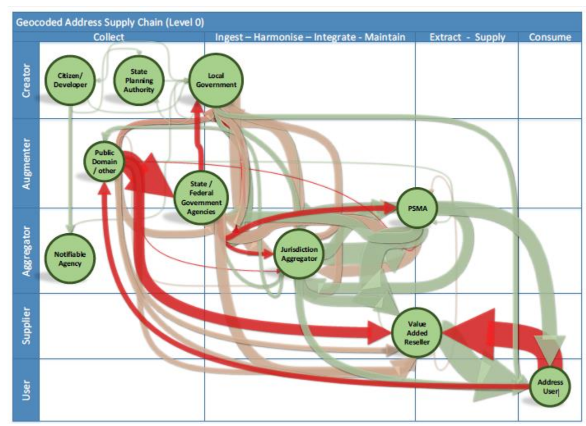

Figure 2. Geocoded Address Supply Chains are non-linear and inherently complex [5].

To achieve improvements in productivity, quality and timeliness, extended supply chains need to be more streamlined. While, automation of processes is a key enabler, so too is understanding the interrelationships between participants engaged in supply chain activities and their business motivation.

III. SUPPLY CHAIN STRATEGY

To achieve a sustainable extended spatial data supply chain, the lesson from the manufacturing industry is to formulate an overarching supply chain strategy [6] to deliver on the goals and vision of all the participants in the business of developing nationwide data products. This initially

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requires an agreed business strategy for the extended supply chain [7].

The business strategy establishes the overall direction that organisations participating in the supply chain collectively aspire to. It includes decisions about what products and services are to be offered, identifies market segments, the timing of product releases and whether products are to be sold or made freely available.

In contrast to the business strategy, the supply chain strategy is the mechanism by which organisations formalize how they work with supply chain partners (suppliers, distributors, customers, and the customers' customers) to deliver on the business strategy [7].

As a whole, the manufacturing industry is good at preparing and implementing comprehensive supply chain strategies. There is a plethora of research in this field; most aimed at driving down operational costs and maximizing efficiencies.

In the spatial industry, anecdotal evidence suggests there are few formally documented extended supply chain strategies. The supply chain strategies that do exist are typically those of individual organisations and their customers and are therefore not necessarily relevant to the needs of the end consumer of a nationwide data product developed downstream. There is often no business incentive to work in the national interest. In the manufacturing industry, this silo approach has shown to result in sub-optimization of the supply chain as a whole and, as a consequence supply chain performance suffers and end-user needs are not met [8].

Spatial infrastructures (globally) tend not to be aligned with a business strategy and therefore formulating a supply chain strategy becomes a difficult task. Without a business strategy, the network of suppliers, producers and distributors have no clear direction on the type of product to generate and where to focus effort; nor how their intellectual property will be protected and what mechanism will be used to measure and generate a return on investment.

National Spatial Data Infrastructure (NSDI) strategies often serve as the business strategy for governments and are a useful starting point for a nationwide spatial data supply chain strategy. The NSDI strategy captures the core purpose for implementing a NSDI and the aspirations of the nation in using spatial technologies for improving and sustaining social, economic and environmental development. Common NSDI goals are for spatial information that is:

- An accurate nationwide representation of the landscape.
- Available in a variety of forms and accessible through multiple channels.
- Used widely in response to emerging business opportunities.
- Easily integrated with economic, social and environmental geographies for evidence-based decision making.
- Produced efficiently and according to sustainable principles.
- An enabler for economic growth and social wellbeing.

However, while NSDI strategies exist they are often not supported by financial models and capacity plans, nor a clear understanding of the market and end-user needs. These aspects are required to engage, incentivize and obligate supply chain participants. As a consequence, nationwide supply chain strategy often goes unaddressed through lack of commitment.

This happens for two main reasons. Firstly, its execution requires a high degree of organisation and collaboration between many suppliers, producers and distributors, and this is difficult without a clear business strategy. Secondly; the core problem is to balance supplies against demand across several nodes and a sound financial investment model is required. This is important. Supply chain participants will have various existing business models and different financial investment perspectives – their imagery suppliers will expect to be paid for services and value-adding activities will need to be resourced. As such, the national spatial data supply chain needs to comprise an overarching business strategy and model that satisfies the business objectives of all participants in the extended supply chain and provides the goals, measures and value proposal of the national data product.

Currently, national supply chain frameworks suffer because participants often have no clear understanding of what business model they are contributing to - commercial, commercial 'free' or public good. With an agreed business model the national supply chain strategy has a blueprint from which to operationalize and sustain national product objectives.

IV. Information Metrics and Measures

SCM systems are embedded in the manufacturing industry. They integrate logistics management and manufacturing operations to coordinate processes and activities. SCM systems are used to link major business functions and workflows within and across organisations into a cohesive and high-performing business model. SCM systems use information metrics to drive business success, provide information about the performance of the overall supply chain and to identify problem areas.

The spatial industry can draw from this experience. Performance measures, targets and quality standards can be used to keep track of spatial data investment decisions and monitor progress towards achieving business objectives for national products.

A review of literature indicates SCM systems are not utilized in the spatial sector, and yet, there are some compelling reasons to do so. The primary benefit is to fulfil end-user demands through the most efficient use of resources. SCM systems provide oversight for capacity planning, financial management and just-in-time delivery through forecasting and production monitoring. In this way, the potential impact caused by a change in operation at one supply chain node can be evaluated ahead of time to understand possible repercussions along the entire supply chain and implications for service delivery [3].

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Spatial data supply chain metrics that focus on performance across the entire supply chain can be used to better understand:

- *Carrying costs:* to measure how much it costs to store data over a given period of time.
- *Production Costs:* to measure efficiency and provide a benchmark for process improvement.
- *Warehouse turnover:* to measure how often and which products are sold/downloaded in a given year.
- *Order Tracking:* to monitor the status of requests for data and updates and associated turnaround times.
- *Inventory to sales ratio:* to measures the ratio of in-stock items, such as imagery, versus the amount of data being used/orders being filled.
- *Product performance:* to measure the rate of consumer satisfaction i.e. product returns, and quality/usability issues.
- *Units per transaction:* to measure the average number of units purchased/downloaded to establish a baseline with which to compare future targets.

Measures and metrics for spatial data, both financial and non-financial, are generally available from individual organisations along the supply chain. This information is usually of an operational and discrete nature and is not an indication of the performance of the entire supply chain. In addition, there is usually no interrelationship between the strategic measures of success of each supply chain participant.

The majority of manufacturing performance frameworks, such as the one proposed by [9], are not suited to spatial data supply chains. While SCM systems utilize diagnostics software to show exactly where bottlenecks occur in manufacturing and where data quality improvement is required, the focus is on building physical products with large inventories and complex transportation logistics. A new approach is required for the spatial domain that captures the value activities at each node, such as integration, generalization and level of accessibility.

Information Management System (IMS) metrics are more aligned with spatial data management. IMS have adopted eSupply chains in which supply chain participants are interconnected via internet technologies at technical, application and business management levels. Similarly to spatial infrastructures, the objective of IMS is to improve the effectiveness of decision-makers by getting the right information, to the right people, in the right format, at the right time [9].

A study by [10] evaluated six eSupply chain performance measures: (a) web-enabled service metric; (b) data reliability metric; (c) time and cost metric; (d) e-response metric; (e) invoice presentation and payment metric; and (f) e-document management metric. The researchers surveyed 120 companies. Results indicate that while companies believe these metrics are important, the challenge was to measure them.

There is an opportunity to re-examine these eSupply chain metrics in light of spatial information supply chain needs. In the spatial industry, supply chain metrics are not well documented with the exception of spatial data quality metrics [11] [12] [13]. However, quality is only one aspect of measure for a spatial data supply chain and there is still much work to be done in this area.

V. Closed Loop Supply Chains

The manufacturing industry has adopted opportunities for backhauling in transport logistics to reduce supply chain costs through collaboration and partnership. Often referred to as closed-loop supply chains [14], backhauls additionally transport items in the reverse direction from customers (usually retailers) to the depot (or warehouse). An example is a supplier of gas canisters. Full canisters are delivered to the customer and empty canisters collected at the same time – saving transportation costs and time.

The concept of backhauls (or reverse material flows) are not new to the spatial industry. Crowdsourcing and trusted partnerships have potential as viable strategic data sourcing solutions for maintainers of large geographic datasets. They have the ability to reduce costs (updates are free), improve data currency (updates are timely), and improve the overall accuracy of information (updates stem from local knowledge).

Crowdsourcing has not been seriously adopted by government mapping agencies where there are concerns about integrating data from potentially unreliable sources into authoritative data sets. Yet, vendors of navigation systems have embraced crowdsourcing to update their mapping base. Google Maps goes one step further. It displays crowdsourced traffic conditions along major routes by calculating vehicle speeds from the GPS-determined locations transmitted from ‘opted in’ mobile phone users. Both methods essentially create a closed-loop supply chain. There is significant opportunity for innovation in this area using volunteered GPS vehicle tracing to record map updates and errors.

Research is the key to increasing the uptake of reverse information flows and falls into four areas:

- resolving the *trust* problem [15];
- data harvesting to collect and verify information rapidly;
- integration of crowdsourced and authoritative data; and
- community engagement strategies to stimulate reverse information flows.

The efficiency and effectiveness of supply chains can be improved by embracing the backhaul concept. Benefits are cost avoidance for data maintenance in the longer term, better engagement with end-users and the community, and increased potential for product innovations.

VI. Supply Chain Traceability

Spatial information products are being used to save lives, prepare for natural disasters, mitigate environmental damage, form legal judgments on land boundaries and make significant economic decisions, such as where to locate infrastructure, source minerals and direct social services.

The importance of this information implies that data products are produced using scientifically proven reproducible methods. Yet this is not necessarily the case. Currently, there is no legal requirement or standard that imposes traceability practices on spatial data products.

As the spatial industry considers outsourcing parts of the spatial data supply chain, consideration needs to be given to tracking products and suppliers, using methods that are reproducible, and incorporate elements of traceability into metadata standards.

The ease with which data can be copied and transformed has made it increasingly difficult to determine the origins of a piece of data and therefore, its legitimacy for a particular usage. Supplier and product auditing needs to go beyond direct relationships with first-tier suppliers.

Understanding where data comes from and how it is created and by whom is important to:

- End-users in determining if data are fit for their purpose.
- Consumers who want to know if data has been produced in an environmentally and socially responsible manner.
- Decision makers needing to know the risks inherent in using particular data and thus their level of accountability.
- Data producers in identifying the need for product recalls and understanding the end-user/consumers of their products.

The drivers for supply chain traceability are similar to those encountered in the manufacturing industry. Challenges include [16]:

- Regulatory pressures and consumer demand for responsibly sourced and produced goods and services.
- Tracking and controlling materials and the processes applied on those materials to create finished products.
- Proactively managing product recalls (or data errors) with near real-time corrective actions.
- Improving customer safety and consumer satisfaction when using products.
- Managing product quality and reducing costs associated with nonconformance.

However, the spatial industry has no automated and fool proof solutions for:

- Backward Traceability: tracing back to the data source.
- Forward Traceability: tracking the end-users of data products.
- Component Traceability: tracking the component parts that makeup the end data product.
- Process Traceability: tracing what processes have been applied to data in the finished product.

A. Backward Tracability

The manufacturing and clothing industry has adopted backward traceability as a means of demonstrating a company's corporate social responsibility. Incidents, such as the 2013 Savar building collapse in Bangladesh, where more than 1,100 workers died because of unsafe conditions, have led to widespread discussions about corporate social responsibility across global supply chains. Law makers are increasingly legislating that manufacturers disclose where raw materials are sourced [17] [18], particularly if sourced from war-torn countries where revenue is funding violent military groups [19].

In the food industry, companies are increasingly sourcing directly from farmers or trusted aggregators rather than purchasing crops that have passed through several layers of collectors. The drivers for this change include concerns about food safety, child labor and environmental sustainability. The aviation industry standards require traceability to ensure the authenticity of parts, aircraft maintenance history and approved supplier identification [20].

From a spatial data industry perspective, CRCSI research is examining methodologies to trace data provenance along the supply chain and be able to present this knowledge in a way that allows end-users to make informed decisions on whether the information is suitable for their purpose. Currently, there are few models that address spatial data provenance from both a detailed metadata and lineage perspective. The CRCSI research is seeking to develop an ontology that goes beyond traditional metadata models that only capture the *who*/*what*/*when*/*why* of information. The provenance model will incorporate process knowledge at the various stages of a data product's lifecycle and include quality measures [21].

B. Forward Traceability

Forward traceability is mandatory in some industries, such as car manufacturing, food and beverage and pharmaceuticals. Forward tracking distribution is necessary in case a product has to be recalled. In 2009 Toyota recalled eight car models and put a halt to production, China recalled 170 tons of melamine-tainted milk powder in 2010 and Unilever United States recalled peanut butter due to potential salmonella contamination [16].

Anecdotally, product recall risk is low in the spatial sector. Nonetheless, being able to trace data usage and consumers will become more important. Today, web portals are extensively used to distribute spatial data but few sites require users to register their details online. This makes it difficult to keep track of who is using data, what their needs are in terms of future product design, and how to let them know that product updates are available.

C. Component and Process Traceability

Radio Frequency Identification (RFID) has revolutionized component and process traceability**.** RFID technology is embedded in many industries including baggage handling, livestock management, toll collection, theft prevention systems and automated production systems [22]. RFID tags are used to automatically identify and track products, materials and parts along the supply chain. The radio-frequency identification (RFID) market is expected to

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rise from $8.89 billion to $27.31 billion by 2024 (23) based on 2014 figures.

The equivalent of the RFID in the spatial domain is the persistent Global Unique Identifier (GUID) or Global ID. The Global ID is a unique identification code permanently assigned to a piece of data (database record) so that information about the data element can be easily retrieved. The importance of the Global ID is that it can be used to unambiguously track a data element through its lifecycle.

However, the value of the Global ID has not been fully exploited in spatial data supply chains. Part of the problem is that organisations that collect and manage spatial data generally only store feature identifiers (ID) that are unique to their systems. This means that when data are integrated from more than one provider there is a risk that the 'system' feature ID will be the same. While IDs can be reassigned, the ability to track data and its lineage along the supply chain, is significantly reduced. Industry needs to consider the application of the GUID in terms of supply chain efficiency (GUIDs support automatic update propagation) and understanding the fit for purpose nature of a data product (GUIDs support provenance modelling).

VII. Communicating Fit for Purpose

Users of spatial information can be faced with a choice of multiple datasets, each containing the information required, but the question is 'which one is fit for their purpose?' Traditionally, the spatial industry has used descriptive metadata to describe datasets – contact information, coverage, accuracy and recommended purpose are all included in the metadata. However, similar data sets have similar metadata and therefore the choice of which one to use becomes difficult. For example, if an end-user searches for a data set containing road information in a particular area, the following may be retrieved:

- polygonised roads in a cadastral dataset;
- highways only, in a road authority dataset; and
- a topologically correct road network in a topographic dataset.

Understanding which product is best for their needs requires experience or subject matter knowledge. The manufacturing industry appreciates that consumers do not necessarily have the information to understand whether a product will suit their needs or not. Manufacturers have embedded methods in production processes to let the consumer know if a product is fit for their purpose. The systems used are based on production standards and their compliance with legislation. For example, toy manufacturers include age suitability on packaging, food producers include nutrition panels and the hotel industry has a 'star' quality rating system. These methods act as a purchasing guide for consumers. They build an expectation that a product will be satisfactory for a given purpose. For example, television codes are a guide to whether or not a program is suitable for a given type of audience based on predetermined criteria (Figure 3). This approach builds consumer confidence as the codes are regulated through a recognised code of practice. There are also systems that put the quality ratings in the hands of the consumer. The internet has become well-entrenched as a vehicle for consumers to rate their experience of a product.

Product: Television Program	**How do I know if a television program is suitable?**	
	A rating and recommendation to audiences based on age and level of maturity; that considers level of violence, coarseness of language, nudity, horror, adult themes, medical practises etc.	**G** Suitable for all
Standards:	**Australian Commercial Television Code of Practice**	

Figure 3. Rating System for Television Programs [24].

The spatial industry does not have a ratings approach for data quality and usability, and has traditionally relied on consumers' understanding of spatial metadata as a means of interpreting whether a data product is fit for a particular purpose or not. However, metadata is often not reliable because it is out-of-date and often incomplete. Interpretation is generally only through descriptive metadata that is at best a subjective interpretation from the perspective of the data custodian. As a result the metadata approach is not user-friendly as it does not consider the needs of the consumer or their viewpoint when determining if a product is suitable. A different approach is required. For example, the food labelling industry in Australia is considering including 'walking time' kilojoule 'burn off' to help consumers make sense of nutrition panels that are difficult to interpret for weight loss programs [25].

Current approaches to providing 'fit for purpose' advice for consumers of spatial information products and services are not adequate. Organisations that move down the fit for purpose track will typically address a single business objective. In addition, the spatial industry has typically relied on self-regulation and many organisations and businesses have adopted their own standards rather than a national data quality standards approach.

There are inherent difficulties in establishing criteria that can be applied across a single data set due to the varying degrees of quality. Data elements are often sourced from multiple suppliers and have been subject to different processes.

In moving towards a new approach the spatial industry needs to firstly, identify and classify the purposes for which spatial information products are used; and secondly, develop a set of criteria with which spatial data products can be rated so that they can be assigned a fit for purpose code. Criteria would be based on:

- Data standards and quantity measures, such as currency, completeness, integrity, accuracy.
- Origin, including method of capture and equipment used.
- Lineage, such as the transformation and processing methods applied.

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VIII. Supply Chain Framework

A Supply Chain Framework has been developed as a guide to formulating supply chain strategy (Figure 4). The framework adopts learnings from the manufacturing industry: where supply chain strategy is the key mechanism by which producers formalize how they work with their supply chain partners (suppliers, distributors, customers, and the customers' customers) to deliver on business strategy.

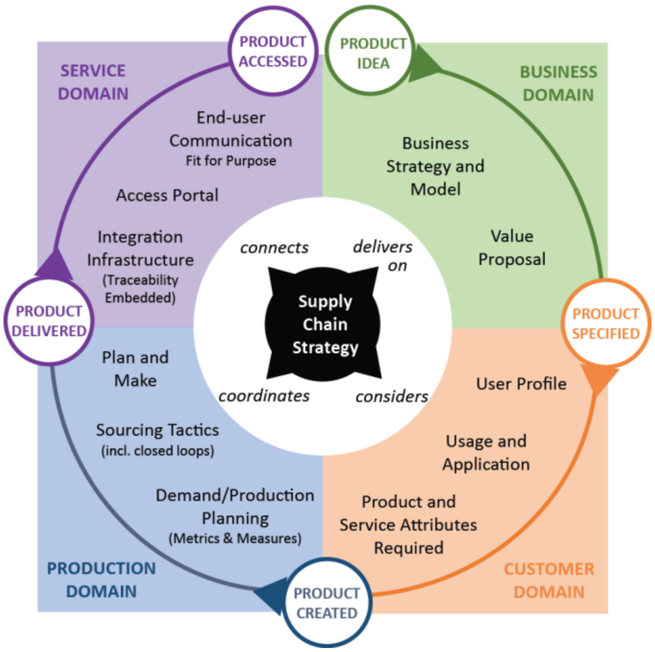

Figure 4. Spatial Data Supply Chain Framework

The framework applies to individual nodes (organisations) along the supply chain where value is created for first tier consumers. It also applies to the overarching strategy required for extended supply chains. The aim of the latter is for all supply chains participants to cooperate in a way that provides value for the end-user.

The Supply Chain Framework considers the life cycle of a data product from its inception as a product idea through to its delivery to customers. The framework includes four domains; business, customer, production and service domains.

A detailed version of the framework (supply chain ecosystem) is currently being used to develop an ontology to link supply chain components across extended supply chains to create value for the end-user.

A. Business Domain:

The supply chain strategy delivers on the business outcomes required including return on investments and business incentives. These are generally specified in the business strategy along with the collective vision, mission and goals of the supply chain partners. The supply chain strategy also considers the value proposition to the end-user. This stems from the collective efforts and activities of the supply chain partners.

B. Customer Domain:

The supply chain strategy considers the end-user requirements, the factors influencing product usage behavior and the design criteria that will create the most value for the end-user, such as timeliness, content, coverage, semantics and accuracy.

C. Production Domain

The supply chain strategy coordinates the external forces that impact on demand planning, data sourcing complexity and the types of transformation processes required to make a data product. A compliance framework is required to support interoperability including data and technology standards, quality measures and metrics, and custodian roles and responsibilities. Collaboration with supply chain partners is a key component to sustaining production in the longer term; as are closed loop systems that capture additional product value through process integration. Future partnerships between nodes are likely to be characterised by digital collaborative environments and automated information flows.

D. Service Domain:

The supply chain strategy focuses on connecting people to products and services. It considers the integration of component products from multiple sources to create standard offerings as well as tailored solutions. A policy framework is required to manage open access to data products balanced with individual privacy, copyright and intellectual property considerations. These aspects are more complex in extended supply chain networks. Communicating product suitability will require a rating system that is meaningful in the end-user's context.

IX. Conclusion

Spatial Data Supply Chains have evolved over time to become complex networks that are difficult to visualise and manage. The relationships between suppliers, producers and consumers in extended (or national/cross-agency) supply chains are difficult to formalise, and understanding the origin of a piece of data is often challenging. The ease with which data can be copied and transformed by individual supply chain participants is creating inherent problems.

A new approach is required to improve the way spatial data products are produced and distributed. The objective is to automate tasks to deliver productivity improvement, cost savings, timeliness and improved data quality. The approach is essentially to strengthen the *push* supply chain model. The second viewpoint is to improve the experience of the end-user by more effectively communicating the purpose for which the data product is intended to simplify consumer decision-making when faced with multiple data sets to choose from.

Drawing on manufacturing supply chain experiences, it is clear that the underpinning issue is to create effective supply chain strategies. The supply chain strategy formalizes how supply chain partners (suppliers, distributors and end-users) work together to deliver on an agreed vision and business goals and provide the incentive to participate and driving opportunities for efficiency and innovation

Supply chain metrics can then be used to drive business success, provide information about the performance of the overall supply chain and to identify ongoing problem areas. As a pre-requisite, having an understanding of existing supply chain costs will better direct where process improvement is most critical.

A more strategic approach to data sourcing is an industry imperative in driving down costs and increasing end-user engagement. Closed loop supply chains are one such mechanism that has potential to deliver efficiencies and increase community participation. Supply traceability combined with methods to communicate the ‘fit for purpose’ nature of spatial products has the potential to improve the experience of consumers when tapping into spatial data holdings.

In many cases, it will be obvious what spatial information can be used for. However, consumers are becoming far savvier about what spatial information products and services are available, and are applying this information to increase business acumen.

The next step in this research is to formulate a supply chain ontology to examine the interrelationships between business strategy, customer requirements, spatial data workflows, metrics and measures, and data access from both a supplier and consumer perspective. The aim is to develop best practice extended spatial data supply chain strategies.

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