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Developing a Basic Formal Supply Chain Ontology to Improve Communication and Interoperability

David Morrow

DEVELOPING A BASIC FORMAL SUPPLY CHAIN ONTOLOGY

TO IMPROVE COMMUNICATION AND INTEROPERABILITY

DISSERTATION

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DEVELOPING A BASIC FORMAL SUPPLY CHAIN ONTOLOGY TO IMPROVE COMMUNICATION AND INTEROPERABILITY

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Abstract

Information is crucial to supply chain performance because it is used to make decisions and trigger actions. Organizations across world-class supply chains increasingly use information technology to analyze and process supply chain data. However, supply chain management lacks a common language, making information exchange difficult.

An ontology can provide a standardized framework that organizes a given knowledge domain. This research proposes a common language for developing a supply chain ontology that can be built into a basic formal ontology understood by both humans and computers.

According to current research, an established and widely used supply chain framework is a good starting point for developing a supply chain ontology. Many researchers recommend using the Supply Chain Operations Reference (SCOR) Model. This framework is translated into a software package that generates a Web Ontology Language (OWL), which can be used by information technology.

This research analyzes the need for a standard supply chain language and identifies a framework to use as a starting point for developing an ontology. Using SCOR 12.0 as the framework, an XML/OWL based model is developed, which can be used by information technology to improve information exchanges between supply chain partners. Supply chain practioners will benefit from an ontology built on the SCOR 12.0 framework that has been digitalized to support information technology professionals and enable supply digital supply chains.

To my wife, thanks for believing in me.

Acknowledgments

First and foremost, many thanks to my wife for loving me and for tolerating all the long, hard days and nights and for your support through the push to the finish. I need to thank my dissertation committee: Dr. Laurence Merkle, Dr. Ben Hazen, and especially the chair, Dr. William Cunningham. I could not have done it without your help and support.

David Morrow

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Introduction

Supply Chains Defined

Although people have operationalized supply chain management (SCM) for thousands of years, SCM as a scientific discipline was not conceptualized until the 1980s (Oliver, 1982). A supply chain can be defined as "the integration of key business processes from end-user through original suppliers that provide product, services, and information, that add value for customers and other stakeholders" (Lambert, 2008, p.2). Vital to this definition are the concepts of integration and information exchange. As shown in Figure 1, the synchronized exchange of information is central not only within an organization but also to external suppliers and customers.

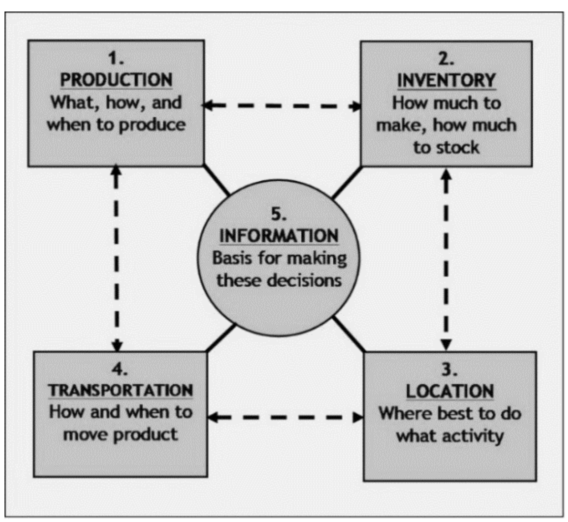

Figure 1. Information Central to Supply Chain Decisions (Reproduced from SCM Globe 2014)

Many generic supply chain representations include the cross-organizational flow of goods, services, and financial transactions, and the bi-directional exchange of information between supply chain partners (Bowersox et al., 2002; see Figure 2). Information and data exchanges within supply chains are the raw material, critical for making sound decisions. To this end, organizations with world-class supply chain capabilities, such as Amazon and Apple, leverage information technology tools to gain an awareness of information, analyze it and execute it to improve supply chain performance (Galloway, 2018).

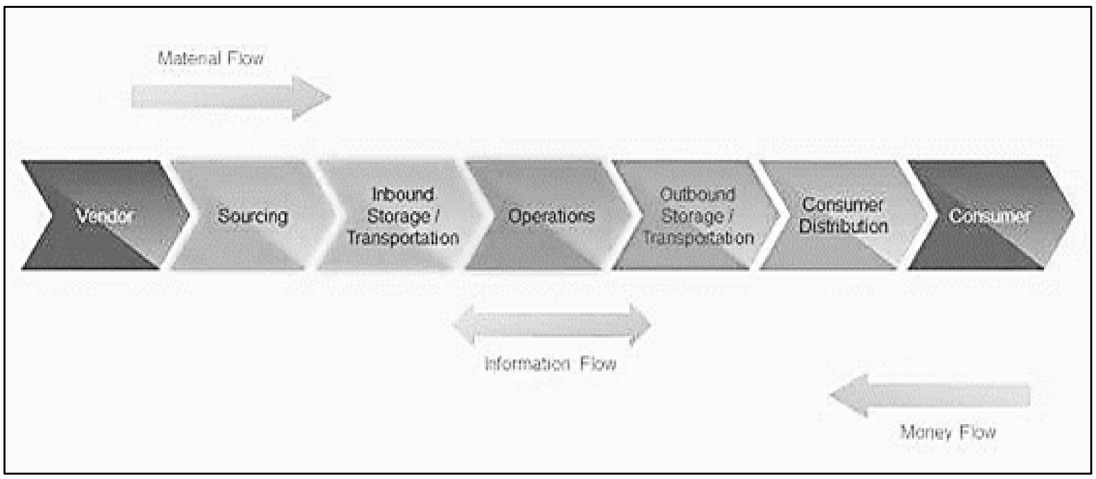

Figure 2. Supply Chain Information Flows (Reproduced from Bowersox et al., 2002)

Understanding Supply Chains

Supply chains are generally studied as a system of coordinated firms called a "network of organizations" that are integrated via coordinated supply and demand (Lambert and Cooper, 2000; Frankel et al., 2008). Another view is that the supply chain is a complex adaptive system emerging from the autonomous actions of the participating firms (Choi et al., 2001; Pathak et al., 2007; Wycisk et al., 2008). Both perspectives view supply chains as complex and dynamic networks of organizations and actors that exchange goods and services as well as information.

Information flow is bi-directional between partners and is used to communicate a need for an action to be taken. This ability to communicate is what separates humans from animals (Wolfe, 2016); however, the enemy of communication is the illusion that it has occurred (Whyte, 1950). Problems of communication are intricate and complex in scope (Chomsky, 1988) and are found in every organization and function, especially supply chains.

Why Supply Chains are Important

Supply chain management is critical to organizational success. In his book *The World is Flat*, Thomas Friedman (2005) suggests that supply chain management is one of the top ten factors making the world more connected and, therefore, flatter. Supply chain management has become so crucial that the locus of competition has moved from organization against organization to supply chain against supply chain (Wang et al., 2017). This has resulted in organizations becoming more interconnected and dependent on supply chain partners, both domestically and internationally (Ross, 1998).

Problems Facing Supply Chains

Modern supply chains face a variety of problems: supply and demand disconnections, cyber security, increasing global competition, as well as an ever-growing list of supply chain risk. However, one fundamental problem with supply chains is the lack of a common language.

The need for a common language and improved integration have grown in importance to supply chains. Whereas many problems can disrupt communication, the lack of a common language is arguably the most problematic. For example, early trade between different countries or cultures was made more difficult due to language differences. This problem was improved, however, with the rise of the British Empire and the widespread adoption of English as the default language of global trade (Clark, 2012; Crystal, 2003). An estimated 1.75 billion of the 7.7 billion global population can speak English (Neely, 2012). English is the default language of international trade and the the language of the World Wide Web (Neely, 2012).

All communication can become distorted due to *noise* (Figure 3). Noise is anything that causes disruptions to communication. This can be in the form of a dropped call, an internet connectivity issue, or a misunderstanding. One form of noise is the lack of a common language used by supply chain partners. This leads to confusion and disconnections between countries and organizations, resulting in sub-optimized demand and supply flows.

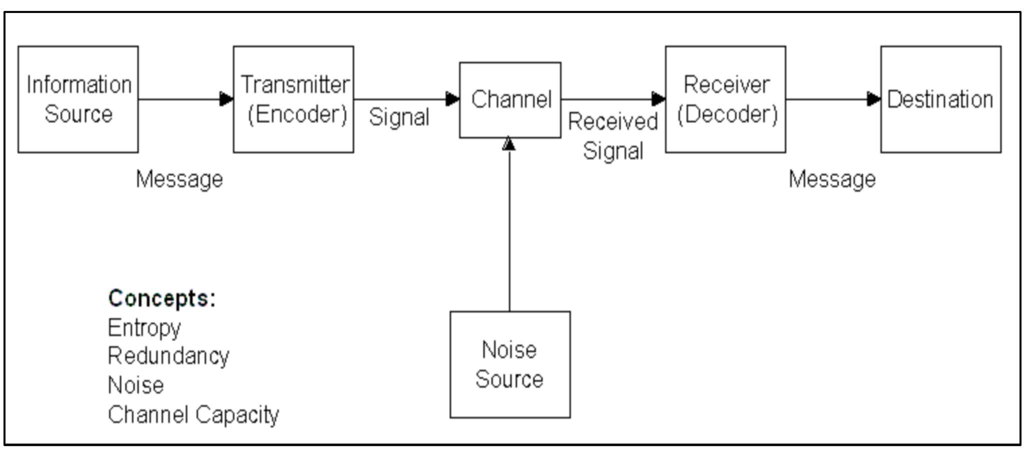

Figure 3. Basic Communication Model, (Reproduced from Shannon-Weaver, 1949)

Many supply chain practitioners contend that overall supply chain performance would improve with better communication between supply chain partners. At a macro level, these interfaces and exchanges between supply partners are in the form of products, services, money, and information (Lambert, 2008). Unlike English, the language of international trade, the terms of SCM are not standard across global, national, and even industrial boundaries. Other factors impacting supply chain performance are increasing global competition, shorter product life cycles, demand for more flexible manufacturing systems, and more significant product variations (Yan and Woo, 2004). To adjust, supply chains need to be faster and more agile. However, because supply chain processes are cross-functional and cross-organizational, business transactions are often hampered by organizational barriers within companies (Lambert, 2008), resulting in increased confusion and inefficiencies.

A common supply chain language can cut through the functional jargon, cultural differences, and different languages, allowing information to be shared with limited confusion and misunderstandings (Ye et al., 2008). This need is becoming even more critical due to the increased emphasis on digital supply chains and the use of computer-enabled decision-making (Sanders and Swink, 2019).

Need for a Supply Chain Ontology

Many researchers (e.g., Böhm et al., 2011; Hermann et al., 2016; Petersen et al., 2016) have pointed out that SCM lacks a common language. In a research paper sponsored by the Centre for International Governance Innovation, Girard (2019) calls for society, industry, and governments to begin setting and implementing international standards. He states that there is an "urgent need to set the ontology, semantics, and definitions" (Girard, 2019). This need is seen by many thought leaders in SCM, who call for a common language and a schema for organizing the knowledge and understanding of supply chains (Botta-Genoulaz, 2010). SCM needs a common language and an ontology in which to frame supply chain knowledge. However, what is an ontology?

An ontology in its traditional, philosophical context is defined as the study of what exists (Effingham, 2013): it is the study of the kinds of things in reality and the relationships they have to one another (Arp et al., 2015). An ontology can provide a standardized framework that organizes a given knowledge domain. It offers a set of terms with consistent definitions and metadata descriptions (data and information used to define data; data about data) that enable information sharing and research across a knowledge domain. It is also used to code knowledge into computer software design (Arp et al., 2015).

Other fields of study have already benefited from using ontologies. For example, the area of biomedical research has benefited from the use of biomedical ontologies, which provide cross-language barriers that allow knowledge and research to be shared internationally. Arp et al. (2015) point out that the biomedical ontologies "promote greater consistency in the description of data." Human languages do this naturally, but computers require formal, unambiguous definitions.

According to current research, an established and widely used supply chain framework is a good starting point for developing a supply chain ontology. One such framework is the Supply Chain Operations Reference (SCOR) model. Portions of the SCOR model have already been used by researchers to prove that it can be leveraged to develop formal ontologies suitable for computer usage. However, these ontologies used older versions of the SCOR model (Botta-Genoulaz et al., 2010).

The need for an ontology is becoming more critical with the growth of digital supply chains, which require more exact knowledge representation. Although humans can ask for clarification when dealing with a certain level of abstraction, computers cannot. Therefore, a standardized supply chain ontology is a critical first step to enable web services and the Semantic Web (Botta-Genoulaz et al., 2010). The Semantic Web is the future envisioned by web developer Berners-Lee et al., (2001), where "the structure of information is understandable to computers so that

[they]… can perform many tasks instead of humans" (Jakus et al., 2013). For example, if a mode of transportation is described as a *boat*, a computer would see it as an error if it were programmed to recognize the limited transportation modes of *plane*, *truck*, or *ship*. A semantic interpretation, however, would see *boat* and *ship* as equivalent values, thus eliminating the error. Whereas this is a relatively simple translation, the effort becomes quite overwhelming when interpreting every supplier and customer in a supply chain.

Kirchmer (2011) sees reference models as a quick and efficient way to complete supply chain process maps, and they have the additional benefit of cost, time, and risk reduction, as well as improved quality, transparency, and a common language. They also have the benefit of benchmarking processes (Kirchmer, 2011).

It has been argued that all supply chains are different. Although this is true at the lowest level of supply chain processes, it is not the case at the higher levels. At higher levels, processes become more standard and universal in definition and in activity. This can aid the understanding of supply chain processes and help to align supply chain activities (ASCM, 2021). Using a common model or framework as a starting point can reduce the level of complexity and ease ontology development, as development would not begin with a blank slate. The concept map in Figure 4 shows how ontologies can become very complex (Novak and Canas, 2006).

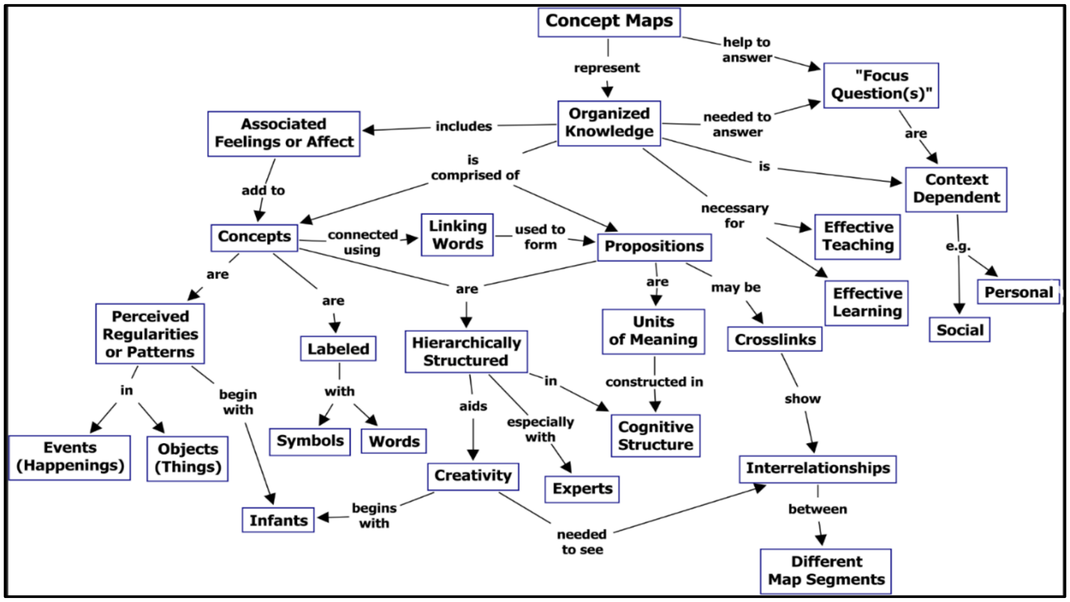

Figure 4. Level of Complexity Mapping Concepts (Reproduced from Novak and Canas, 2006)

In a recent effort to develop a supply chain ontology, SCORVoc, Petersen et al. (2016) used the SCOR 11.0 model as the basis on which to build robust and efficient information flows within supply chain networks. However, they only developed an ontology for the order/invoice process and did not include any other processes. One reason for this limited approach was that the effort resulted in over 150 pages of Web Ontology Language coding. Many more processes and data interchanges will need to be developed before the ontology is useful for supply chain application.

Research has identified SCOR as an adequate framework from which to build a more formalized ontology, understood by both supply chain professionals and computers. Although the work of Botta-Genoulaz et al. (2010) and others has shown that building a formal ontology based on SCOR is possible, these efforts have been accomplished using an older version of SCOR (SCOR 6.0, 8.0 and 11.0). The most recent version of SCOR, SCOR DE (Digital Edition), is not yet available to the general membership of ASCM. The SCOR DE version has a very different process configuration that will be considered new to individuals who are more familiar with the structure of SCOR versions 10 thru 12. In addition, SCOR DE expands the scope of supply chains to include product development and customer service processes absent in the operational architecture of some supply chains. SCOR 12.0 is the most recent version of the framework available for membership use that provides an updated representation of today's supply chain operations. Updates and enhancements to SCOR in version 12.0 include many practices concerning digital technologies as well as a revised and enlarged set of enabling processes that expand areas such as technology management and procurement.

Digital supply chains are growing in importance. They promise improved data reliability and computer processing, resulting in faster decisions. However, if digital supply chains are to deliver on these improvements, it will need a robust and rigorous ontology. Developing this ontology will require a proven research methodology.

The design science research methodology best fits this goal. It improves understanding and provides a workable solution to the problem of needing of a basic formal supply chain ontology. Simon (1996) first presented the methodology in his book, *The Science of the Artificial*. He argues that traditional research methodologies work quite well where the subject being studied is a natural phenomenon, but do not render the desired results when the subject is man-made, or artificial. When analyzing the artificial, such as supply chain ontologies, it is essential to understand the problem, and then propose a workable solution to the problem (Simon, 1996). Although this methodology is relatively new, it has been used effectively in medicine, engineering, and information technology (Dresch et al., 2015). However, there is no evidence of this methodology being used in supply chain research (Halldórsson and Arlbjørn, 2005).

This research effort focuses on creating a better understanding of a supply chain ontology's purpose and applications. By creating a basic formal ontology for supply chains, improved communication, understanding, and integration should result (Arp et al., 2015). Specifically, this paper will answer the following research questions:

RQ 1: What key elements are required to develop a basic formal supply chain ontology?

RQ1a: How can design science inform the creation of a basic formal supply chain ontology using these elements?

RQ 2: What is the most appropriate reference model to use as the foundation for a basic formal supply chain ontology?

RQ 3: What uses stem from the development of this model?

Information technology is at the heart of improving supply chain interconnectivity and integration with suppliers and customers. This document presents a basic formal supply chain ontology designed to define and organize supply chain information in a more consistent manner. This can lead to lower costs of transactions, faster processing speeds, and improved understanding and interpretation of the data. Organizations that fail to understand their data will risk falling behind competitors who are already using their own supply chain information to make better and faster decisions.

The remainder of this document is organized as follows. Chapter 2 reviews the prior research relevant to supply chains and the importance of information. This is followed by Chapter 3 outlining the methods used to complete the research and build the basic formal ontology. Chapter 4 shows how the basic formal supply chain ontology was developed. Finally, conclusions, recommendations for future research, and the implications for researchers and practitioners are presented in Chapter 5.

Literature Review

This literature review addresses supply chains as a system. It also examines several models used to understand interactions between forces affecting supply chains. Finally, it reviews future and current trends in supply chain digitalization. This focus shows that supply chains are complex systems shaped by autonomous organizations working together to deliver goods and services to the customer.

The philosophy of supply chain management (SCM) has long been characterized by a strategic orientation (Mentzer et al., 2001b) that indicates the general direction an organization is heading or wants to go in the future. Angerhofer (2000) reviews the research and development of systems dynamic modeling in SCM, while Burgess et al. (2006) illustrate the classification of SCM articles into disciplines that include strategy, psychology/sociology, information/communication, and operations management. Frankel et al. (2008) analyze the contributions of the foundational SCM disciplines of purchasing, operations management, logistics, and marketing, and Mello and Flint (2009) discuss the application of grounded theory in the relative field of logistics research. However, fundamental to understanding supply chain integration is its linkage to system thinking (Defee et al., 2010).

Supply Chains as a System

Researchers in the field of SCM generally study supply chains as a system of coordinated firms, or "network of organizations," that integrate supply and demand (Lambert and Cooper, 2000; Frankel et al., 2008). This network of organizations is further understood as a complex adaptive system, in which a system emerges and adapts based on the autonomous actions of the individual participating firms (Choi et al., 2001; Pathak et al., 2007; Wycisk et al., 2008).

A system is created to fulfill specific purposes and is modified or abandoned if ineffective in achieving those purposes. Within supply chain networks, organizations perform autonomously under physical, economic, and regulatory constraints, with the objective of growing shareholder value (Closs, 2016). In contrast, organizations that purposely work together in achieving optimal supply chain performance can receive individual gains that they would not achieve otherwise (Stanton, 2018). These firms recognize the systemic and strategic results of managing upstream and downstream flows across suppliers and customers in a supply chain. They have what Mentzer et al. (2001a) describe as a Supply Chain Orientation (SCO).

To understand supply chain information flows, the connectivity between the various components needs to be identified and analyzed. Boardman and Sauser (2006) state that "this calls for a dynamic determination of connectivity, with interfaces and links forming and vanishing as the need arises." This establishment of connections by integrating key business processes, which run the supply chain's length and cut across firms and functional departments within each firm, is fundamental to SCM (Croxton et al., 2001).

Change is accelerating, creating opportunities that deliver a competitive advantage to firms and supply chains that act quickly (Stalk, 1998; Schlegel and Trent, 2015). This competitive advantage can even be a hedge against negative supply chain events or risk (Schlegel and Trent, 2015). For example, Ericsson failed to see the impact of a minor fire at a Texas Instrument Facility and almost went out of business. However, competitor Nokia acted on the information and was able to lock up the critically short supply of an in-demand component. This advantage enabled them to capture a larger portion of the emerging cellular market (Elahi, 2010). Time-based competition has arrived and is now the new norm.

Understanding how supply chain systems naturally evolve and change can be achieved by first understanding how they emerge. Emergence occurs when an entity gains properties or capabilities derived from its interaction with other entities; such as supply chain members. The study of emergence is closely tied to the ability to specify a large, complicated domain via a small set of laws; its hallmark is the sense of much coming from little (Johnson 2002). Emergence can be seen in nature as well as in man-made systems such as supply chains. As such, emergence is evident within and between systems.   The former possesses a more deliberate, designed-in emergence whereas the latter could exhibit unrestricted, unforeseen emergence (Gorod et al., 2008).

The law of requisite variety or flexibility (Ashby, 1957) is the variety of functions a supply chain demonstrates on an as-needed basis. The law holds that if a supply chain has does not have enough degrees of freedom or options to respond to uncertainty, then it is at a competitive disadvantage. This means that supply chain diversity is beneficial because it allows supply chain partners to focus on their core competency and leverages the integration between them to achieve the synergistic effects demonstrated by successful supply chains (Lambert, 2008). Increasing supply chain agility through linking and unlinking supply chain partners is an essential aspect of an organization's supply chain execution capability and competitiveness (Hammer, 2001).

Supply Chain Integration

A review of SCM literature reveals a variety of models that affirm the importance of supply chain integration. Lambert and Cooper (2000) have developed the framework depicted in Figure 5. For a complex network to be manageable, they argue, its members should be distinguished between those that provide value-adding activities (primary members) and those that provide resources, knowledge, and utilities for those members.

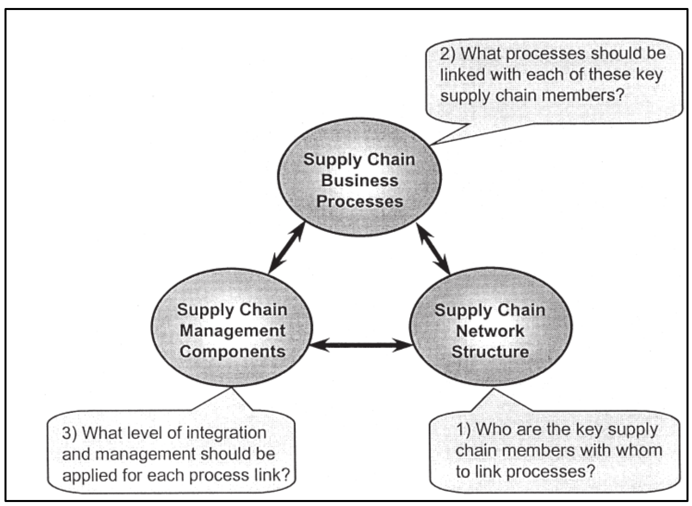

Figure 5. SCM Framework Linking Components, Processes, and Network (Reproduced from Lambert and Cooper, 2000)

It is not appropriate, Lambert and Cooper reason, to integrate and manage all business processing links and interactions through the supply chain. Some links are simply more important to the success of the organization than others. For example, the link to a single source supplier of an important product component in a growing market is more important to proactively manage than a link to the waste pickup supplier. They have identified four types of connections, shown in Figure 6: managed, monitored, not managed, and non-member process links. It follows that these different links are tied to processes that are conducted by differing supply chain partners on a variety of levels.

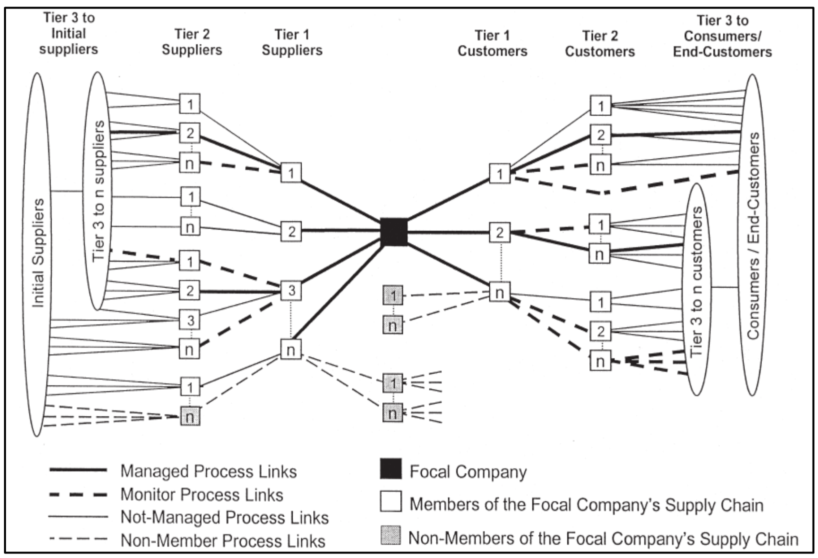

Figure 6. Intercompany (SCM) Business Connections from Sub-Tier Suppliers to End Customers (Reproduced from Lambert and Cooper, 2000)

Fawcett and Magnan (2002) identified three levels of supply chain management practices, each with increasing layers of complexity. At the first level, SCM applies information technologies to increase the speed and quality of the information exchanged between firms. At the second level, firms include linked information systems, inter-organizational processes, common goals, shared risks and rewards, and consistent performance measures. At the third level, SCM is recognized as a philosophy and culture that guides decision-making and relationships. As Figure 7 shows, the complexity increases as firms progress from level one to level three, with an increasing need for greater integration at a deeper level than can be met with just a contractual arrangement. At this deeper level, supply chain partners understand that they are each important to one another's individual success.

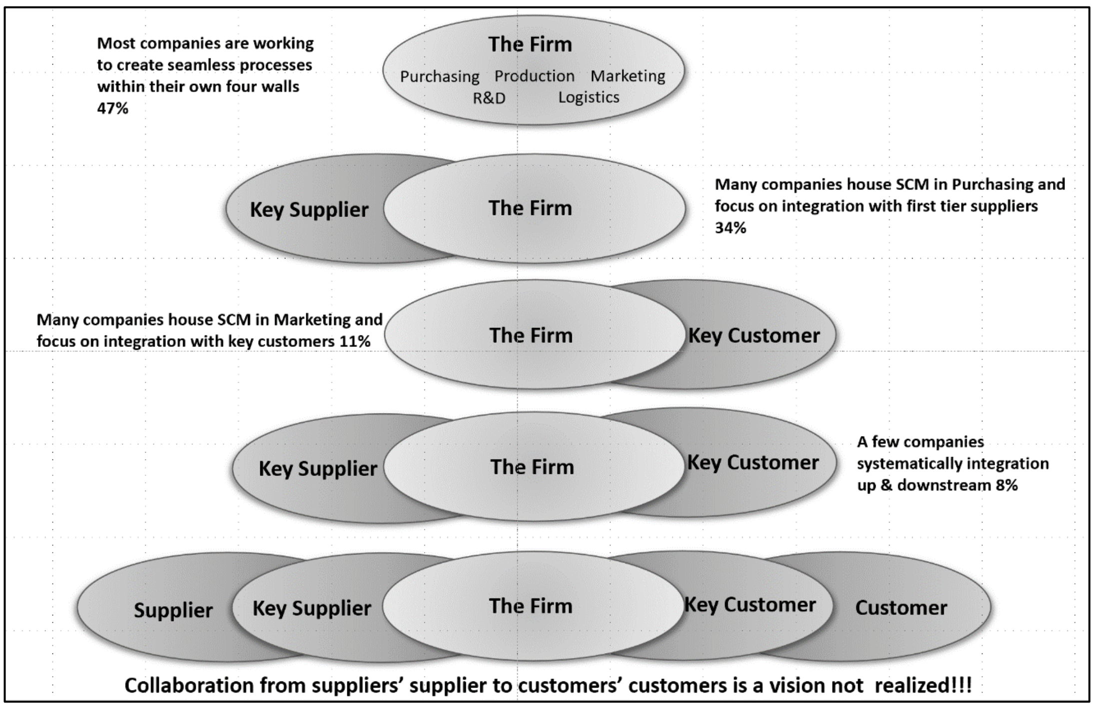

Figure 7. Increasing layers of Complexity (Adapted from Fawcett and Magnan, 2002)

Chen and Paulraj (2004a) developed a framework (shown in Figure 8) that identifies the influential forces impacting supply chain relationships. These forces are as follows: environmental uncertainty, customer focus, top management support, competitive priorities, information technology, purchasing, logistics, the supply network structure, buyer and supplier relationships and performance. These forces are seen as factors that can either act independently or in concert to impact a supply chain's overall success or failure.

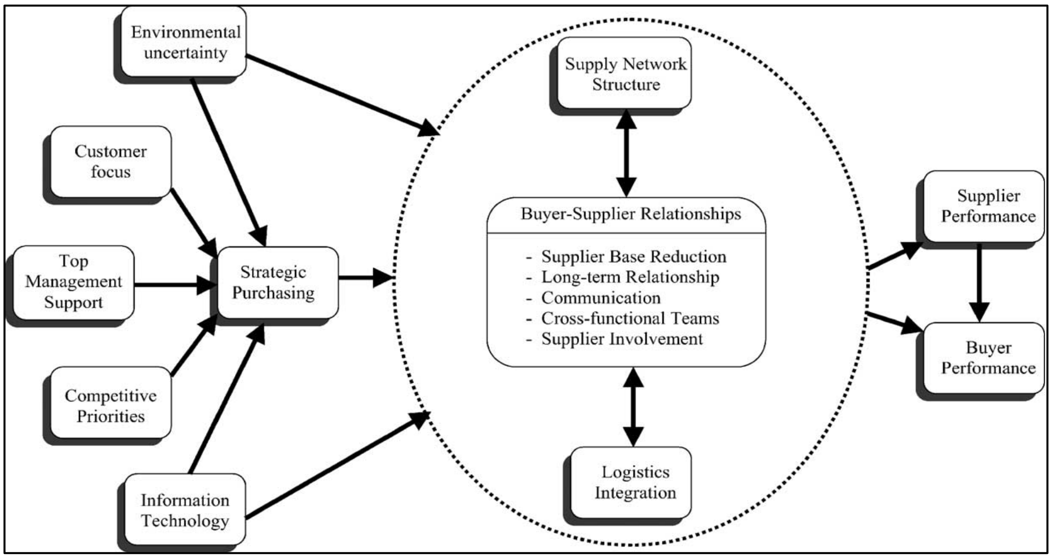

Figure 8. Factors Impacting Supply Chain (Reproduced from Chen and Paulraj 2004a)

Viewing supply chains through the three strategic dimensions of synthesis, synergy, and synchronization can aid in understanding the strategic importance of each supply chain interface (Giannakis and Croom, 2004). The synthesis dimension refers to the structural aspects of the supply chain and is concerned with decisions affecting a firm's strategic position, the scope of vertical integration, the configuration of the supply base, and the channels used to reach customers. The synergy dimension arises from inter-organizational relationships and focuses on supplier selection, customer relationship management, and inter-organizational behavior. Finally, the synchronization dimension involves logistics, operational research, operations management, information management, and system engineering concerns such as scheduling and product flow.

An important aspect of supply chain (SC) interfaces is the need for supply chain partners to collaborate. These interfaces must be built-in and work properly if they are to be successful. Cooper et al. (1997) argue that "the driving force behind SCM is the recognition that sub-optimization occurs if each organization in the SC attempts to optimize its results rather than integrate its goals and activities with other organizations to optimize the results of the chain." Mentzer, DeWitt and Keebler et al. (2001) define supply chain orientation as "the recognition by an organization of the systemic, strategic implications of the tactical activities involved in managing the various flows in an [sic] SC."

It is important that the integration and interfaces within a supply chain are defined correctly so that critical elements can be identified and their importance understood and managed properly. The Institute of Electrical and Electronics Engineers defines integration as "the ability of two or more systems or components to exchange information and to use the information that has been exchanged" (2011). In contrast, Vernadat (2007) defines integration as a system's ability to communicate with another system and use the information to perform some function. Both definitions focus on a system's ability to exchange information and use that information as a critical aspect of integration. However, both definitions stress the importance that the receiving system can correctly process the information exchanged. Therefore, integration is the ability of two or more systems to exchange information: both the sender and the receiver have a similar understanding of the information and what actions to take or not to take. If supply chain partners are to be truly interoperable, they must communicate in a common language understood by all systems or else suffer a modern-day Tower of Babble effect.

Need for a Standard Supply Chain Language

A standard supply chain language is needed for more efficient connections (Ye, et al., 2008). Currently, firms spend time and effort to establish terms, data definitions, metric calculations, and general engagement rules before transactions can take place (Böhm et al., 2001). Despite the effort required, millions of supply chain partners worldwide connect and disconnect daily (Lambert et al., 1998).

Information is needed to understand supply chains as emerging systems defined by integration efficiencies, but it is crucial to first understand the interfaces between their components or partners. Because each firm develops independently, the supply chain that emerges is an aggregate of their interactions. In this context, supply chain managers are enlightened architects that must focus on the interface standards on a variety of levels and applications to ensure effective communication (Misraet et al., 2010; Guitarte, 2015).

When supply chains lack a common language, the partner with sufficient market power establishes the communication terms (Girard, 2019). This benefits the partner powerful enough to dictate the terms. Moreover, this leads to higher switching costs and negatively affects overall supply chain agility. Larson et al. (2007) find that the lack of a common SCM perspective is a significant barrier for SCM implementation.

As supply chains increasingly become more integrated, digital, and global, the lack of a shared language becomes more problematic. Whereas the flow of information within the supply chain has always been critical, the advent of digital information and technology has only enhanced the need for a common language (Sanders and Swink, 2019). Because data and communication are crucial to supply chain success, it is one of the most significant areas needing improvement (Oxford, 2019). This is not just an external problem but also an internal one that disrupts communication and hampers cooperation between departments and suppliers (Oxford, 2019). Increasing global and domestic change can disrupt communications between supply chain partners, which can result in economic losses.

Challenges with Supply Chain Performance

The issues with the lack of a common supply chain language can result in problems in defining and measuring supply chain performance. Researchers disagree on business performance measurement systems (BPMS; Dumond, 1994)—its features, roles, and basic processes (Franco-Santos et al., 2007). Historically, financial metrics are foundational to any valid BPMS. However, Eccles (1991) describes the benefits of using both financial and non-financial measures to determine strategy. He challenges practitioners to begin designing BPMS by asking the question: "Given our strategy, what are the most important measures of performance?" This question is still valid today and is essential when determining a given supply chain's performance.

However, supply chains are becoming more complex and performance measures struggle to accurately assess the important factors for success. Fundamental to supply chain performance are the various strategic implications dictated by the level of collaboration between the supply chain participants, the formulation of partnerships, the sharing of information, and the amount of integrated logistics management and planning. The resources and managerial effort that firms are willing to invest in SCM are products of improved customer service and reduced cost from improved SCM performance (Pavlov, Bourne, 2011). Kennerley and Neely (2002) contend that BPMS consist of three components, all of which point to the need for a robust methodology:

- individual measures for the quantification of the efficiency and effectiveness of actions,
- a set of standards for the assessment of the performance of an organization as a whole, and
- supporting infrastructure for data acquisition and analysis.

Despite various research efforts in BPMS, it remains a barrier to successful supply chain collaboration (Fawcett et al., 2007).

A robust BPMS should facilitate communication and enhance motivation by feeding back information on progress and supporting problem diagnostics. This is especially important for supply chain managers, considering that their ability to coordinate supply chain activities depends on successful communication goals and the actual performance of key supply chain partners (Stephens, 2001). Therefore, it is crucial when designing supply chain measures that special attention is paid to the definitions of data elements and metric calculations. Moreover, metrics should be designed in conjunction with an overall architecture or framework, allowing key performance indicators to be supported by lower-level diagnostic metrics that enable root cause analysis.

Improved integration positively affects supply chain performance in two ways: first, by improving collaboration between the firms and second, by showing the importance of improving the supporting infrastructure. Min et al. (2005) describe cooperation as an ultimate core capability that provides benefits like revenue enhancements, cost reduction, and operational flexibility. Holmberg (2000) states that structure determines behavior and is composed of tangible things like information technology. To understand how positive behavior is determined and measured, Holmberg stresses processes, definitions, metrics, and data as crucial factors for successfully restructuring supply chain measurement systems.

Information Demands of Supply Chain Digitalization

The increasing use of Industry 4.0 technologies, such as the Internet of Things (IoT), connects supply chain partners, increasing the need for a common supply chain language (Petersen et al., 2016). Whereas human supply chain actors can ask for clarifications when unsure about the meaning of a term or measure, communication between digital actors requires a more rigid syntax (Arp et al., 2015).

As supply chains become increasingly digitalized, their actors are expected to increase dramatically across all industries. In areas such as supply chain planning, computers are being utilized to either supplement human actors or replace them (Sanders and Swick, 2019). However, as with many emerging trends, the digitalization of supply chains is fraught with confusion and hype (Sanders and Swick, 2019).

Digital supply chains need to be defined as distinct from the digitalization of supply chains. Digital supply chains are characterized by computer-aided supply chain actions. Technologies, such as the Internet of Things (IoT), cloud computing, advanced analytics and big data are all examples of information processing capabilities of a digital supply chain. However, to become digital requires that the supply chain in question become digitalized.

The Gartner IT Glossary defines digitalization as the use of digital technologies to change an organization's business model, providing new revenue and value adding opportunities (Gartner 2021). Technopedia defines digitalization as the process of converting traditional analog supply chain signals into a digital format understandable by information technology (Technopedia, 2021). The Technopedia definition is the one that will be used in this paper.

Digital supply chains are capable of rapid re-planning based on updated demand, revised supply levels, and higher supply chain agility levels. Supply chains are currently generating data that demands higher analysis levels to promote better decision making and a deeper understanding of competitive forces (Girard, 2019). Data proliferation from digitalizing supply chain information will put significant pressure on data analysts to analyze more data and to quickly generate meaningful insights. This demand is linked to the trend of weaponizing data and information by competing organizations and supply chains.

A recent survey of supply chain leaders reveals that organizations are predicting revenue increases of 60-75% from digital supply chains in the near future (Hansen et al., 2018). The era in which supply chains compete against other supply chains has arrived (Rice and Hoppe, 2001).

While connected technology devices have greatly improved lives, they are not without concerns. For one, many connected devices are susceptible to hacking, and can be easily taken over to do harm. Examples include internet-enabled cars being taken over by hackers and smart phones used to spy on their users. Internet-capable sensors that manage electrical transformers have even been hacked to override safety levels, causing the transformers to blow up (Stanton, 2018). Also, according to computer scientist Jeff Voas of the National Institute of Standards Technology, "there is no formal, analytic or even descriptive set of building blocks that govern [sic] the operations, trustworthiness, and lifecycle of IoT components" (Kevan, 2018).

Many see blockchain technology as a disrupter of a magnitude similar to that of the 1990's internet. Some envision that it will transform governments, economies, organizations, legal systems, and supply chains (Bambara and Allen, 2018). A promising aspect of blockchain technology is the cost and time saved in international transactions. These savings are achieved by eliminating brokerage bankers, who traditionally ensure the secure exchange of money or credit. Blockchain technology eliminates this need inasmuch as trust is built into the technology via open transactions that are visible to all parties. Neither party can make changes to the blockchain without the other party knowing.

Blockchain technology can trace the origin of a product using transaction histories, which are available to all parties and cannot be changed without their knowledge. This capability provides a way to verify the source of a product that may pass through several supply chain partners. For example, billions could be saved annually by pinpointing the source of contaminated produce and thus eliminating the need to throw out uncontaminated produce.

Blockchain information could also be used to facilitate customs inspections by allowing agents to quickly identify which items to inspect and which to allow to pass through (Bambara and Allen, 2018). Finally, perhaps the most critical aspect of blockchain technology as it affects supply chains is the development of "smart contracts" (Gilchrist, 2018).

Smart contracts are blockchain-enabled contracts that contain embedded logic that enables contract execution without human intervention. When a transaction is completed, funds are transferred automatically. These smart contracts can even have performance measures and metrics built into them, improving the monitoring and management of supplier agreements. This would greatly benefit supply chain organizations since their actions would be automatic, in real-time, and more importantly, would not require a human actor (D.Tapscott and A.Tapscott, 2016). This would allow supply chain professionals, already short on time, to focus on other aspects of supply chain management. However, this type of automated technology requires a firm and formal set of terms and definitions that could be supplied by a supply chain ontology (Bambara and Allen, 2018).

Need for a Supply Chain Ontology

An ontology is a rigorously defined framework that provides an understanding of a shared domain and is also heterogeneous for widely spread application systems (Ureten and Ilter, 2006). Ontology is a term that has recently been used in discussions concerning the semantic web, in which an ontology is the basis for developing a set of machine-readable definitions that create a taxonomy of classes and subclasses and define the relationships among them (Arp et al., 2015).

Although many models exist to understand supply chains, most are limited to one dimension, such as models used for procurement and strategic sourcing. Supply chain practitioners are left to integrate these focused models into a consolidated view of their supply chain, or use a model that joins the various activities into a single supply chain representation or framework. Three of the more widely used models are from the Supply Chain Management Institute, the American Productivity and Quality Center, and the Association for Supply Chain Management (formerly APICS). Although many supply chain researchers have analyzed and even attempted to build supply chain models, none of the models have been adopted universally. Therefore, the need for a widely accepted framework and supporting ontology remains.

Why an Ontology?

In the last few years, ontologies have grown in importance due to a growing need to organize web information into meaningful constructs that aid automated searches and processing (Gasevic et al., 2006). For example, Europe's data should be available and understandable in all other regions of the world (Arp et al., 2015). This is even more important for supply chains that are dependent on technology such as smart contracts and blockchain.

Ontology is a term borrowed from the discipline of philosophy, which is the study of reality and knowledge (Effingham, 2013). The union of epistemology and ontology has become an increasingly dominant approach for managing information in any knowledge domain (Arp et al., 2015). For example, the fields of biology and biomedicine have worked to ensure that information generated is understood and represented in an agreed-upon format that allows others to validate findings and build upon them. This approach has inspired a collaboration of computer and information scientists, biologists, clinicians, researchers, linguists, logicians, and others interested in developing an ontology for their field (Jakus et al., 2010).

An area of interest concerns data being stored in such a way that makes sharing the data with other related data sets problematic. According to a recent survey of healthcare data scientists, the greatest challenge is the diversity of data types available and not the quantity. The same problem has been observed by one expert who, before the U.S. Congress in July 2014, testified that there is a need for all electronic information to be interoperable, shareable, and reusable (Arp et al., 2015). This problem also plagues supply chains.

Supply Chain Ontology/Framework

Integrating business processes is fundamental to supply chain management. Integration refers to improving the interrelations and interactions between people, processes, and technology (Kirchmer, 2011). Vernadat (2007) recognizes the need for a holistic approach to business integration that includes strategy, business processes, and interoperable enterprise systems. In addition, three integration purposes are identified: communication, cooperation, and coordination. Although reference models are useful for process mapping (Kirchmer, 2011), they are insufficient for sharing information between supply chain partners (Botta-Genoulaz et al., 2012). Finally, firms are competitive when businesses and technologies are aligned (Botta-Genoulaz et al.2012).

Methodology

An ontology enables the exchange of information between and within organizations, as well as across functions in supply chains. This proves to be an ongoing challenge for integration due to a lack of a shared vocabulary and a common understanding of the meaning of supply chain terms. While human actors can ask for definitions and clarification, this is not the case with information required for the digitalization of supply chains. The Web Ontology Language (OWL), however, is designed to integrate translations between differing vocabularies (Allemang and Hendler, 2001).

Several methodologies used for SCM research were evaluated for this research subject. Larson et al. (2004) identify seven commonly used supply chain management (SCM) research methods: surveys, interviews, focus groups, case studies, experimentation, simulation, and modeling. Although the research methods of surveys, focus groups, and interviews were the most commonly used, they do not appear useful for developing a supply chain ontology. Furthermore, case studies, experimentation, and simulation also seem inappropriate for such a development effort. Although modeling was seen as a potential methodology, it was determined to lack the depth of development used in traditional supply chain modeling research. What is needed is a research approach that would build artifacts that could serve both humans and digital actors engaged in supply chain activities in the real world, yet make a scientific contribution to the understanding of supply chains.

Design Science Research (DSR) methodology was identified as a research methodology that could meet this need for a practical application and further add to the understanding of SCM. Whereas traditional scientific research seeks to understand a problem and recommends solutions, DSR focuses on improving the system being studied. The DSR research approach "consolidate[s] knowledge about the design and development of solutions, to improve existing systems, solve problems, and creates [sic] new artifacts" (Dresch et al., 2015). While the use of this approach is growing, it has already been used successfully in medicine, engineering, information technology, and organizational research.

DSR owes its success to producing artifacts that interface with internal and external environments. This pragmatic method focuses on developing solutions that, though not always optimal, can be implemented in the current supply chain environment, benefitting the user community. Since it has a cost and solution orientation, many regard DSR as an applied science (Dresch et al., 2015).

A number of different DSR approaches have been proposed, including the problem-solving cycle, the synthesized research approach (Van Aken et al. 2012, and Cole et al. 2005, respectively), and research methods offered by Peffers et al. (2007) and Gregor and Jones (2007). They all build on the work of Simon in his book *The Science of the Artificial* (1996). The Design Science Research Cycle (Alturki, 2011) was determined to be a suitable research approach for developing a supply chain ontology due to its focus on analyzing alternative solutions, constructing the solution, testing the solution, and, finally, communicating the results to researchers and practitioners. Alturki's 14 step Design Science Research Cycle was expanded by Dresch to a 15-step approach. In addition, Dresch's model derives from the synthesis of the ideas of several other authors and is especially useful in the research of information systems (Dresch et al., 2015). Dresch's 15-step DSR process is as follows:

1. Document the idea or problem to be studied.
2. Investigate and evaluate the importance of the problem or idea.
3. Evaluate the new solution feasibility.
4. Define the research scope.
5. Determine if research is with the design science paradigm.
6. Establish type of research contribution.
7. Define the topic/subject (construct, evaluation, or both).
8. Define requirements.
9. Define an alternative solution to the problem.
10. Explore existing knowledge to support the proposed alternative.
11. Prepare for development and evaluation.
12. Construct (development) new artifact.
13. Evaluation (Artificial evaluation) of artifact.
14. Evaluation (Naturalistic evaluation) of artifact.
15. Communicate results.

The remainder of this chapter is organized around Dresch's 15-step DSR process. First, it briefly summarizes the problem under study and its importance, as required by Steps 1 and 2 and discussed at length in Chapters I and II. Discussion of the new solution's feasibility (Step 3) comprises the bulk of the remainder of the chapter, which concludes with brief discussion of the remaining steps.

The first step of Dresch's 15-step DSR process is to document the problem. The problem addressed in this research, as documented in Chapter I, is a lack of a common language in supply chain management. This is a starting point for the development of a basic formal supply chain ontology.

The second step of this approach is to investigate and evaluate the problem's importance: Is it a big problem now, or will it be in the future? As shown in the literature review, many supply chains are using information technology, such as blockchain, artificial intelligence, and automated monitoring devices, to enable quicker and more responsive digital supply chains. Information exchanges are critical to supply chain operations; therefore, a formal language linking these processes and technologies together would improve product and service velocity due to reduced time needed to interpret the meaning of a demand.

A standard language for SCM improves interoperability between supply chain partners because it reduces the cost of switching partners. This results in lower prices and increased global competition and innovation. Finally, it reduces excess inventory and stock-outs resulting from language disconnects and misinterpretations between supply chain partners, both human and machine.

The third step is to analyze the possible solutions. Here the objective is twofold. First, determine what approach will work for both human and machine actors within the supply chain. Second, determine if there is a viable option that provides a starting point for developing a solution.

Requirements for Developing a Basic Formal Ontology

Ontology development lacks a standardized process; however, there are some best practices that should be followed. First, include experts in the development of an ontology (Arp, et al., 2015). Surprisingly, this seemingly obvious advice is sometimes overlooked. For example, an effort to develop a common financial ontology was undertaken in Europe with limited input from financial experts. The resulting ontology was reportedly an eloquent design deemed unusable by users (EDM Council, 2017). Second, use mind maps or simple knowledge graphs to capture information structure and exchanges. Finally, use an open-sourced, widely-used application, such as OWL, to capture the basic formal ontologies (Uschold, 2018). Adherence to such practices eases the development of basic formal ontologies by using a lightweight ontology as a foundational basis.

Basic formal ontologies are more rigorously defined because computers cannot make the intuitive leaps that humans can. For this reason, encoding computer-readable information that can be shared on the web is very important to supply chain partners, as it provides a standard coding that could be used by their IT applications. This is becoming more important due to increased reliance on computer information technology and decision support. Web-enabled technologies rely upon HTML and XML as a common language for communication. In order for software programs to effectively process information, structured and defined meta-data is required. In addition, there is a growing need for this type of encoding to support information sharing via the Semantic Web (Allemang and Hendler, 2001).

The Semantic Web is defined as "Communication protocols and standards that would include descriptions of the item on the Web, such as people, documents, events, products, and organizations, as well as relationships between documents and relationships between people (Alesso and Smith, Thinking on the Web, 2009, 281).

The Semantic Web supports "computers performing complex tasks and answering difficult questions" (Lacy, 2005). Because the Semantic Web leverages existing web languages such as HTML and XML, the World Wide Web Consortium's (W3C) Ontology Group developed OWL as an open standard for enabling the Semantic Web. OWL uses Uniformed Resource Identifiers (URI) and XML namespaces as a means for virtually anything to be described so that information technology can understand and use it. This semantic relationship allows supply chain actors to automatically retrieve information from a trading partner in the format they need to properly process the information signal. This retrieval capability can considerably reduce the need for translating information from one system to another, preventing misinterpretations.

The W3C Semantic Web Stack and its supporting architecture are shown in Figure 9. Central to the W3C Semantic Web Stack is an ontology built using OWL, the enabling capability supported by a unifying logic, formal rules, and SPARQL query language. Although the logic of the Semantic Web Stack must be understood from a top-down perspective, it is enabled by technology developed from the bottom up.

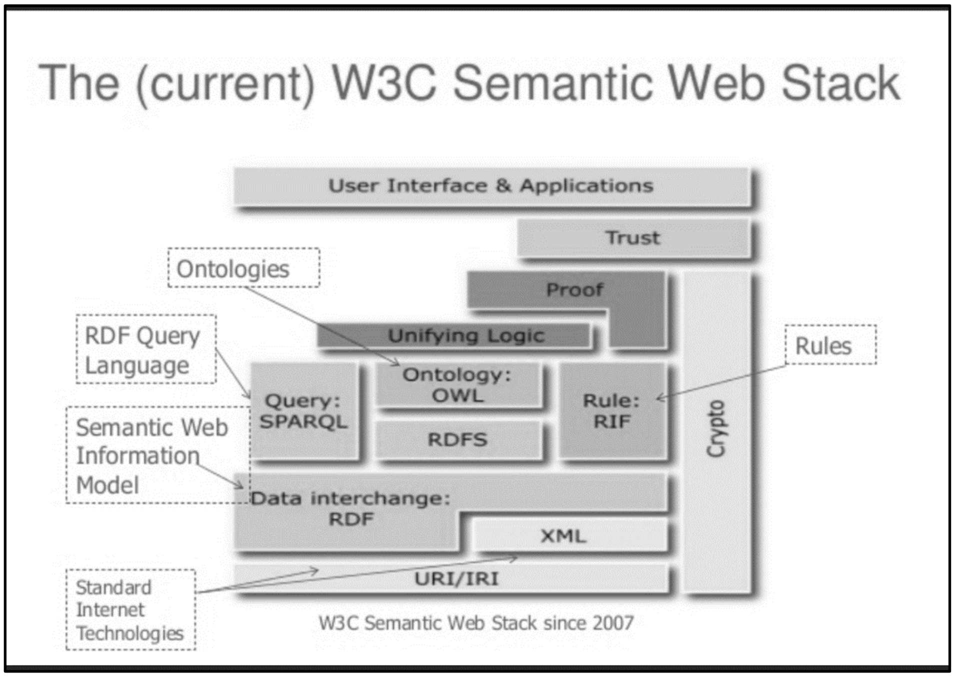

Figure 9. URI, XML, RFD, and RDFS Build to Ontologies Central to the Semantic Web (Reproduced from W3C 2012)

Building the W3C Semantic Web Stack

The URI and XML namespaces form the base layer for developing an OWL construct, as shown in Figure 9. From this essential starting point, XML and XMLS datatypes are generated in a consistent, standardized, computer-interpretable syntax. Information in this serialized and encoded form enables data sharing between many commercial applications, making XML a commonly used standard for exchanging data on the web.

As shown in Figure 9, the XML and XMLS datatypes then form the basis for Resource Description Frameworks (RDF), the essential relational language layer of the Semantic Web architecture. Used to specify OWL instances, RDF represents the “most important value-added layer of the Semantic Web architecture” (Lacy, 2005). Like grammatical sentences, RDF statements consist of a subject, or resource; a predicate, or named property; and an object, or data value. This allows RDF/XML statements to be linked in statements of attributes and value pairs associated with resources (Lacy, 2005).

The next step in OWL development is to turn RDF statements into a Resource Description Framework Schema (RDFS). Whereas the RDF is an abstract data model for making statements about resources the RDF/XML publishes in serial form the RDF statements. The RDFS provides a standard vocabulary for describing concepts or meta-vocabulary. To further illustrate, the RDFS contains elements for a domain-specific collection of descriptions that extend vocabularies using explicit semantics. For example, the RDFS formalizes the semantic concepts of classes, properties, individuals, generalizations, and restrictions (Lacy, 2005).

The OWL, having been developed from the RDFS, enables more expressive descriptions of semantic relationships than would be possible with RDFS alone. Considering that an OWL is a set of axioms describing classes, properties, and the relationships between them in a specific domain, the resulting ontology enables agile domain tools to support reasoning and a new functionality (Lacy, 2005).

However, it must be determined whether a viable framework for developing a basic formal ontology for supply chains exists, which would significantly reduce development effort and increase adoptability by supply chains globally.

Possible Models/Frameworks for Developing a Supply Chain Ontology

Several current supply chain models may provide a useful starting point for the development of a basic formal ontology. Using a model as an abstraction layer aids in organizing and standardizing process descriptions, reducing the amount of data mapping as well as providing a semantic link between organization and industry terminologies (Siebel 2019). The supply chain models discussed so far were designed to help people understand the fundamental interactions and integration points between supply chain actors, but they do not have the level of documentation needed to form the basis for developing an ontology. Nevertheless, several supply chain models warrant examination due to their depth of processes and universality to supply chains globally:

1. **APQC Process Classification Framework**: The scope of the American Productivity and Quality Center's (APQC) (2019) Process Classification Framework extends beyond the supply chain to include operating processes and management and support services (Figure 10). The framework is organized into five operating processes. These five processes are organized into level one organizational categories that decompose to level two process groups. The level two process groups are further decomposed into level three processes that further decompose into level four activities. In addition, the Process Classification Framework includes a cross-industry version, useable by any organization in any industry, as well as industry-specific versions, such as those for aerospace and defense that become more clearly defined depending on the industry. Use of this model generally falls into three

categories: benchmarking, content management, and process management/governance. Benchmarking involves defining a process and linking metrics to that process. Individual values for metrics are captured and shared anonymously with members of APQC at no additional charge. Content management is a file structure that organizes company content and documents by using the standard organization framework, generic information about what the process captured, and company-specific information to complete the content. Finally, the purpose of a process is added to a company's description. The APQC Classification Framework provides companies a way to reengineer a given set of processes by allowing them to identify processes that align via with the framework, enabling changes to their processes where warranted (APQC, 2017).

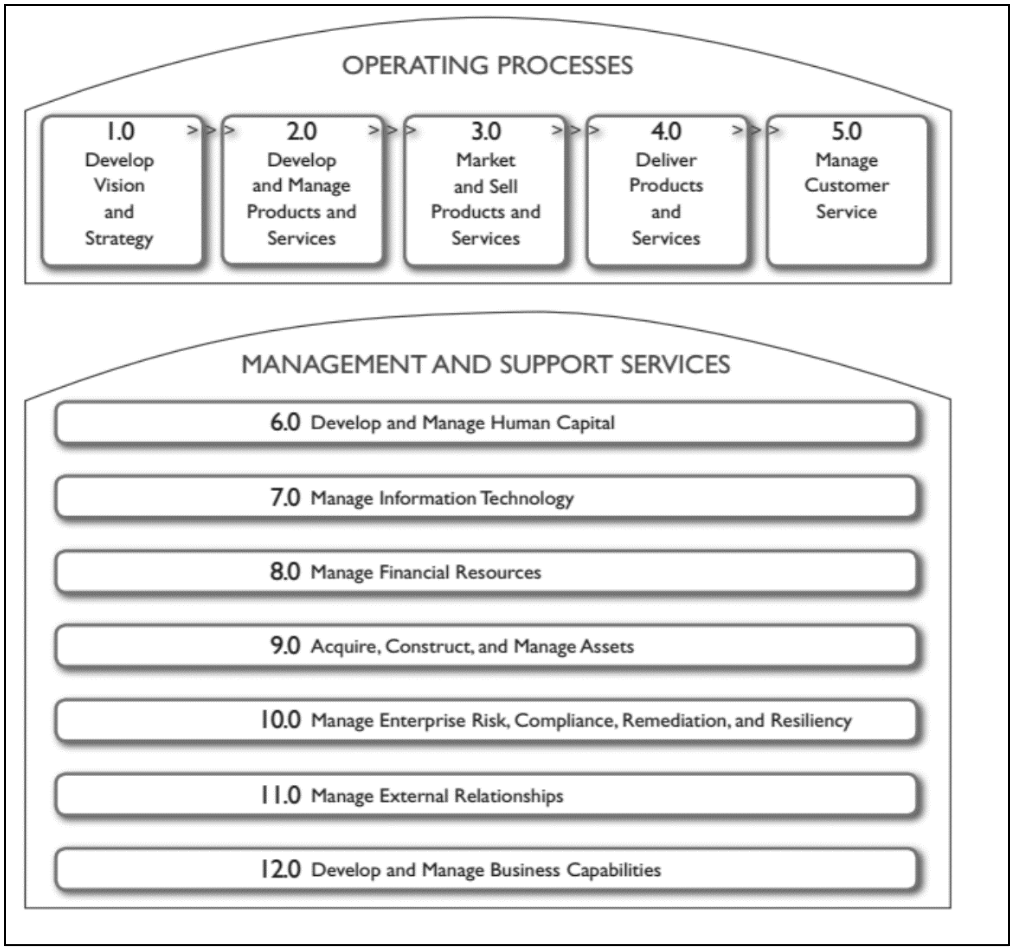

Figure 10. Level One APQC Framework (Reproduced from APQC, 2017)

2. **Global Supply Chain Forum:** This model, shown in Figure 11, is based on a set of eight supply chain business processes: customer relationship management, customer service management, demand management, order fulfillment, manufacturing flow management, supplier relationship management, product development/commercialization and returns management. Each process is further defined by supportive strategic and tactical subprocesses (Lambert, 2008).

Performed by participating supply chain partners such as suppliers and customers, the eight processes are linked with six general functions of an organization. For example, the marketing department provides plans and resources to support customer relationship management, as shown in Figure 11, while the finance department provides customer profitability information. Each of the six functions, marketing and sales, research and development, logistics, production, purchasing, and finance, update each of the eight supply chain processes (Figures 11 and 12).

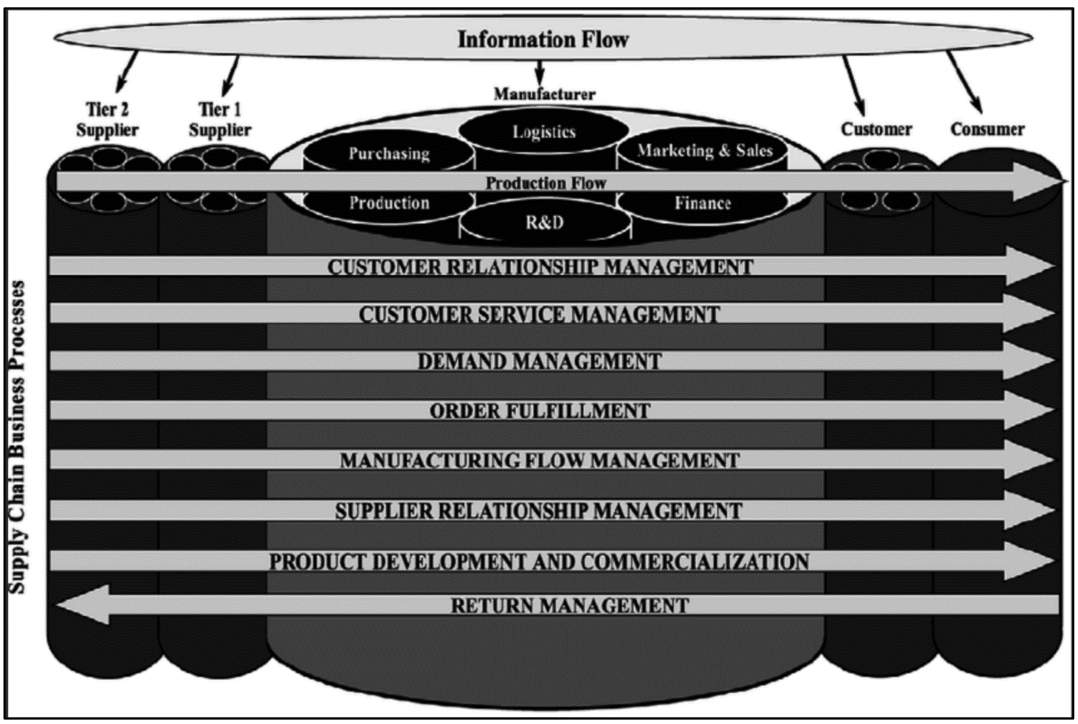

Figure 11. Global Supply Chain Forum Model (Reproduced from Lambert 2008)

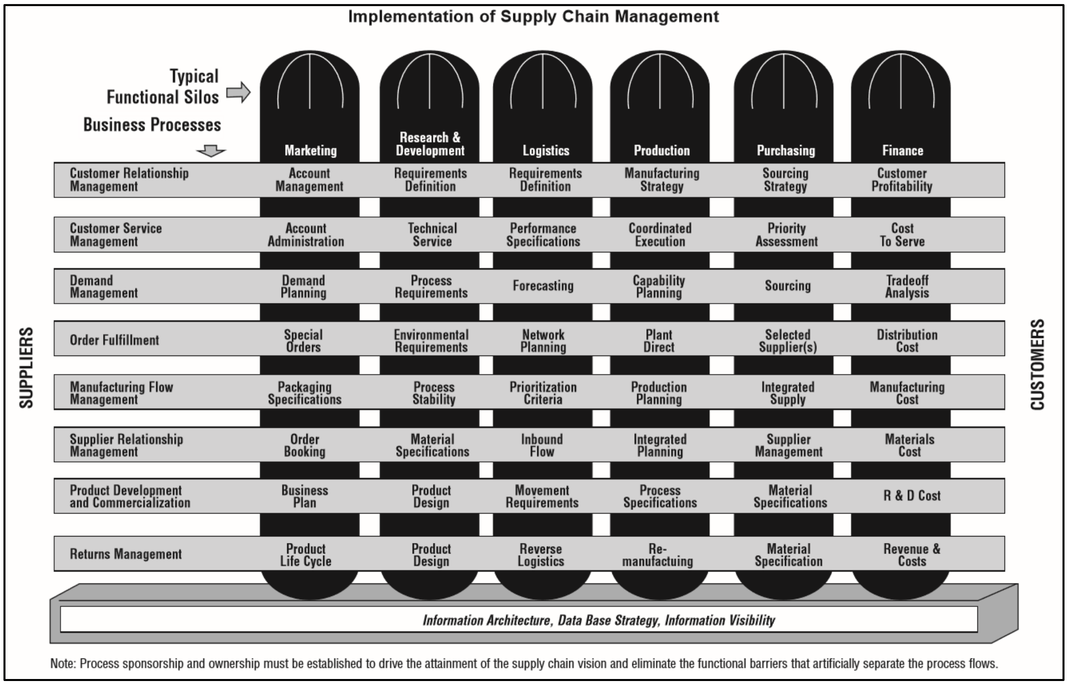

Figure 12. Supply Chain Functional Integration (Reproduced from Lambert, 2008)

3. **Supply Chain Operations Reference model (SCOR):** Over 25 years old and now on version 12, this model originated from many leading corporations and researchers interested in a model to further understand supply chain processes. Similar to a work breakdown structure, the model contains level one to level three processes, which are not organizationally or functionally defined. Figure 13 shows level-one processes, which are the primary actions of any supply chain organization: *plan*, *source*, *make*, *deliver, returns*, and *enable*. The processes of *source*, *make*, and *deliver* are execution processes, whereas *enabling* is the set of processes that support other supply chain processes. In addition, the *plan* process involves planning supply chain activities and

ensures that the other planning processes are aligned to support the overarching supply chain plan. Finally, the process of *returns* handles those from customers as well as suppliers. In comparison, level two processes represent the configuration level of the model. For example, within the level one process *make*, there are three level two process configurations: *make to stock*, *make to order*, and *engineer to order*. Finally, level three processes represent flows within the supply chain and show how processes, metrics, best practices, and recommended skills are linked to one another.

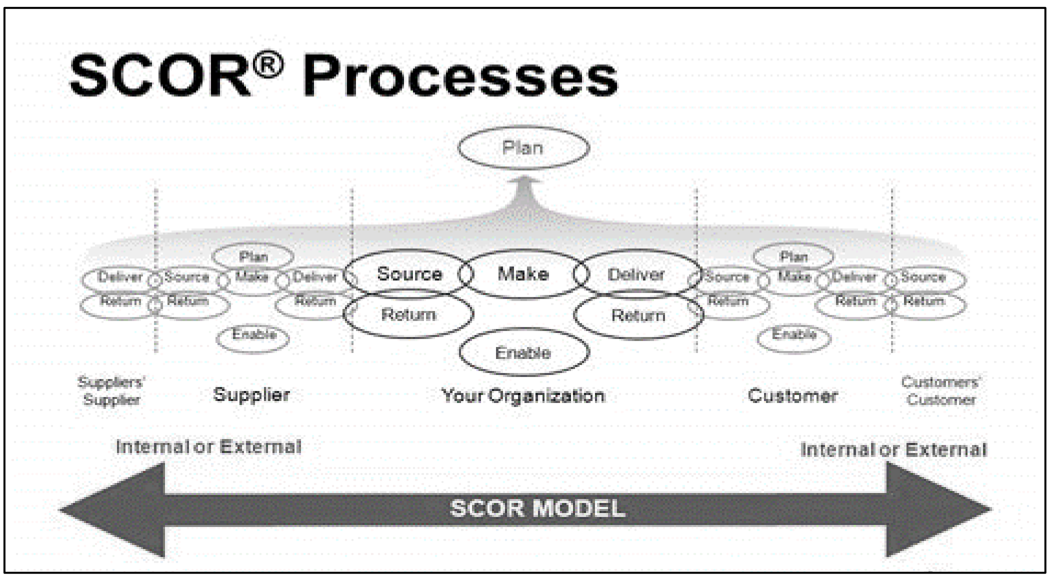

Figure 13. SCOR Model Level-One processes (Reproduced from ASCM, 2019)

The SCOR model contains a set of metrics that are organized in a tiered fashion. This tiered structure allows for the Key Performance Indicators to be analyzed according to the supporting tier two and three metrics. In addition, the SCOR model contains a set of skills and practices that can be referenced as process improvement opportunities. Finally, the SCOR models v6.0 and 8.0 have been used to develop a limited ontology (Botta-Genoulaz et al., 2010; Böhm et al., 2001).

4. **UN/CEFACT:** The United Nations Center for Trade Facilitation and Electronic Business Reference Data Model (UN/CEFACT) (2017) organizes data business information entities engaged in international trade. It uses the information to harmonize cross-border transactions, improving efficiency. The UN/CEFACT uses an internationally accepted modeling technique to analyze the global supply chain. Part of the UN Core Component Library, the model focuses on supporting international trade and customs. As shown in Figure 14, the model defines three level-one processes: *buy*, *ship*, and *pay*.

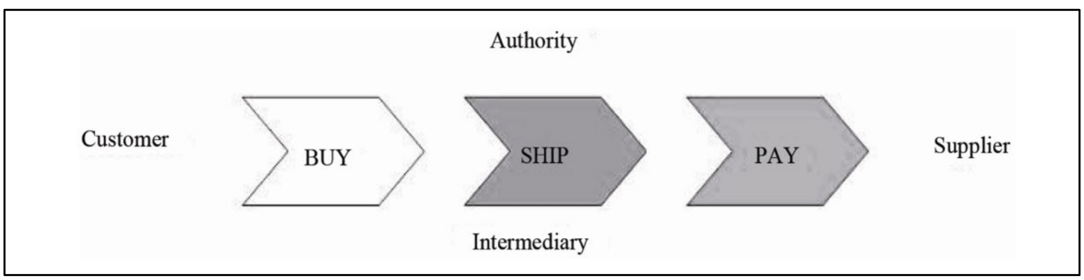

Figure 14. Level-One Processes of UNCEFACT Model

The business process layer of the model (not shown) manages a transaction's electronic documents and resists identifying trading partners. Next, the messaging layer establishes communication between the two trading partners. Finally, the content layer deals with documents and other important trade data (Asosheh et al., 2012). Currently, the model defines multi-modal transport but is limited to international transportation (United Nations Centre for Trade Facilitation and Electronic Commerce, 2017).

Criteria for Model Comparison

Leveraging the work by Arp, Smith, and Spears on best practices for domain ontology design, the general principles of realism, perspectivism, fallibilism, and adequatism were determined to be useful in selecting a viable model from which to build an ontology. Each of these four principles will be presented and discussed as they relate to their definitions and use in this evaluation.

Realism is defined as “a philosophical position according to which reality and its constituents exist independently of the representation” (Arp et al., 2015, 44). Simply stated, it is the model representative of reality as understood as universals and their relationships or of someone’s concept of reality. It can be argued that no one has actually seen a supply chain in its entirety, nor does the model representation provide a close understanding of supply chains in reality. It was determined that while all four models represented some aspect of the supply chain, only the UN model did so in practice for international trade. However, the SCMI, APQC, and SCOR models provided a good representation of the supply chain.

Perspectivism in this context is the principle that ontologies have limited capability in capturing all knowledge in a domain. When evaluated by this criterion, the SCMI, APQC, and SCOR models show coverage of the supply chain domain while the UN model only covers international trade.

The principle of fallibilism involves the understanding that all models are imperfect and must be adjusted and corrected over time. When the principle of fallibilism is applied to the SCMI and UN models, it shows that there is no way to update and revise them. Although the APQC model does not specifically show that it has been updated and approved over time, there are updates that capture new best practices as well as update and maintain benchmark data. In contrast, the SCOR model shows version control and changes that have been made over time. For example, the latest version has added new enabler processes for changes in information technology, procurement, and digital supply chains. In addition, corrections have been made where needed, such as moving the supply chain risk metric from the cost metrics category to the agility category (SCOR 8 to SCOR 9).

Finally, the principle of adequatism holds that the ontology should identify the different types of entities that exist in the given knowledge domain instead of attempting to explain them away. Using the criteria of adequatism, the SCMI, APQC, and SCOR models all show the capability to identify a wide variety of supply chain entities and not exclude entities.

Because of the importance of reusing ontologies, a model's ability to be used in a wide variety of supply chains is considered, specifically, the ability to link the supply chains to the model. While all four models show that a wide variety of supply chains can be mapped to their processes, only the APQC and SCOR models contain this mapping as part of the model's usage. However, the SCOR model is used more globally and has a longer history of supply chain use.

Because supply chain management is an essential part of any business or government, the supply chain models should be able to link to models in other knowledge domains. The SCMI, APQC, and SCOR models all have this capability.

Finally, each model was researched to determine if it has been used to develop an ontology in the past. Of the four models, only the SCOR model was used to develop an ontology. This is an important criterion for model selection, as past models provide lessons that can be learned as well as the validation of a completed ontology.

The information above is summarized in Table 1. In addition, this information answers the question of what key elements are required to develop a basic formal ontology (RQ 1).

Table 1: Model Comparisons

Framework	SCM Focus	Realism	Perspectivism	Adequatism	Fallibilism	Ontology Developed
APQC	Yes	Yes	Yes	Yes	Yes	No
SCMI	Yes	Yes	No	Yes	No	No
SCOR	Yes	Yes	Yes	Yes	Yes	Yes
UN/CEFACT	No	No	No	No	No	No

As Table 1 shows, the SCMI, APQC, and SCOR models show positive marks for each criterion, with the SCOR model having the added advantage of being used to develop several supply chain ontologies. Therefore, the SCOR model is selected as a starting point for developing an ontology.

Finally, the analysis using these criteria answers the second research question (RQ 2): What is the most appropriate reference model to use as a foundation for a basic formal supply chain ontology? As shown above in Table 1, SCOR 12.0 provides the best framework from which to develop a basic formal ontology.

SCOR as a Suitable Starting Point

The SCOR model was created in 1997 through the collaborative efforts of the consulting firms Pittiglio, Rabin, Todd & McGrath (PRTM), AMR Research, and corporations such as Bayer, Compac, Proctor & Gamble, Lockheed Martin, IBM, and others (Bolstorff and Rosenbaum, 2002). The original model was designed to provide a deeper understanding of the mechanics underlying supply chains and also as a useful tool for improving supply chain performance. The model was successful because it offered supply chain professionals a common framework of processes, metrics, and best practices developed by supply chain professionals and was designed for practical, real-world supply chain problems. In addition, the SCOR model has been used by many supply chain academics for their research projects.

In 1996, PRTM and AMR established a user-based organization, the Supply Chain Council, which developed the original SCOR model. Over the past twenty years, refinements to the SCOR model included defining skills needed to execute specific supply chain processes, standardizing metrics for measuring processes, and a growing list of best practices. These are all linked to processes within the SCOR model, providing users with an integrated model (Bolstorff and Rosebaum, 2002).

SCOR History

SCOR has evolved over the years to reflect the current understanding of supply chains and leading best practices. The earlier versions of SCOR had only four processes at level one: *plan*, *source, make*, and *deliver* (Figure 15). It provided a standard language designed to improve operating efficiency and understanding, as well as a common set of metrics for analyzing and improving supply chains.

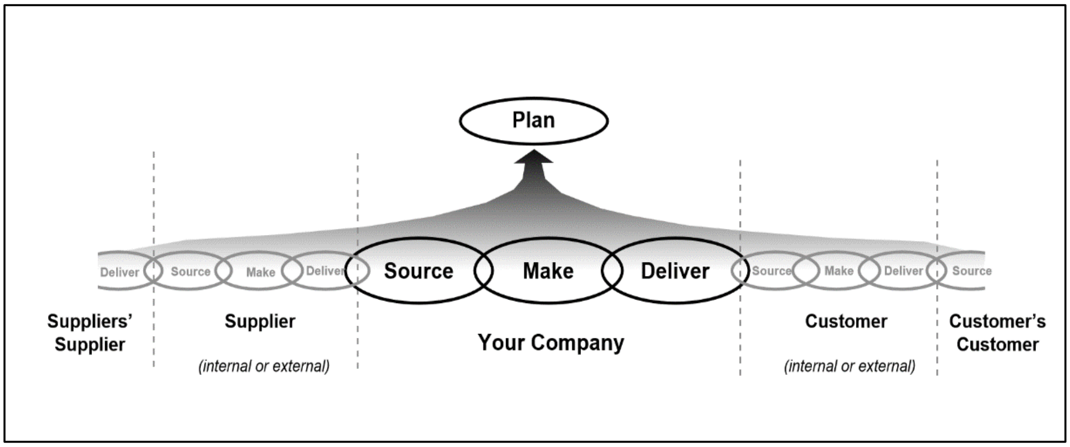

Figure 15. Level One of SCOR V 1 & 2 (Reproduced from SCC, 1998)

The next iteration of SCOR saw a substantive expansion of the model's scope using the metrics and performance attributes. Finally, the model included a *return* process expanding the model to five level-one processes (Figure 16) as well as the incorporation of a supply chain risk enable process. By this time, the Supply Chain Council had grown to over 700 members worldwide with international chapters.

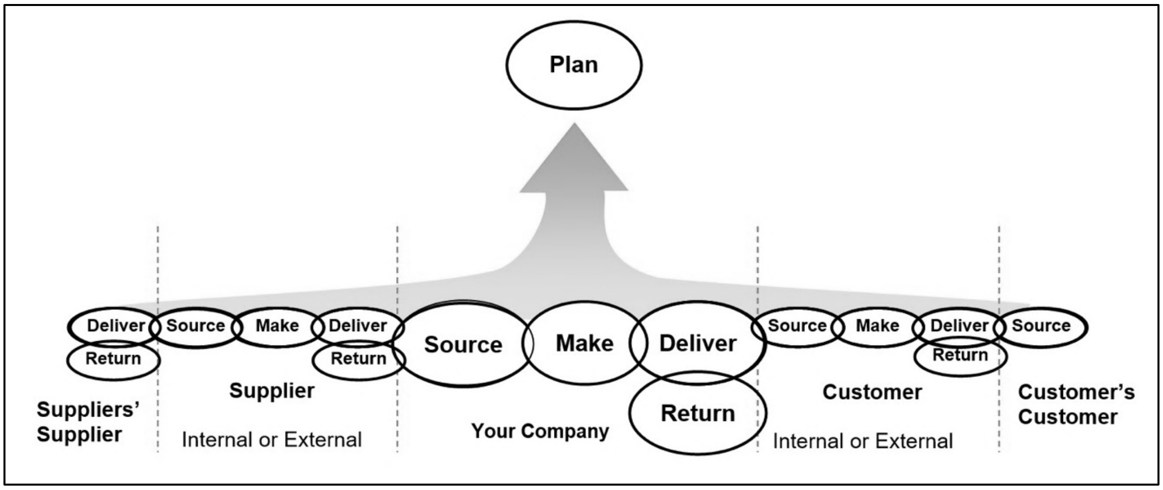

Figure 16. SCOR 4.0 (Reproduced from SSC, 2000)

The third major evolution of SCOR saw the enabler functions modeled as separate processes instead of residing within each of the level-one processes. The other major change was the addition of a section on skills and training recommended for various processes and technologies (Figure 17).

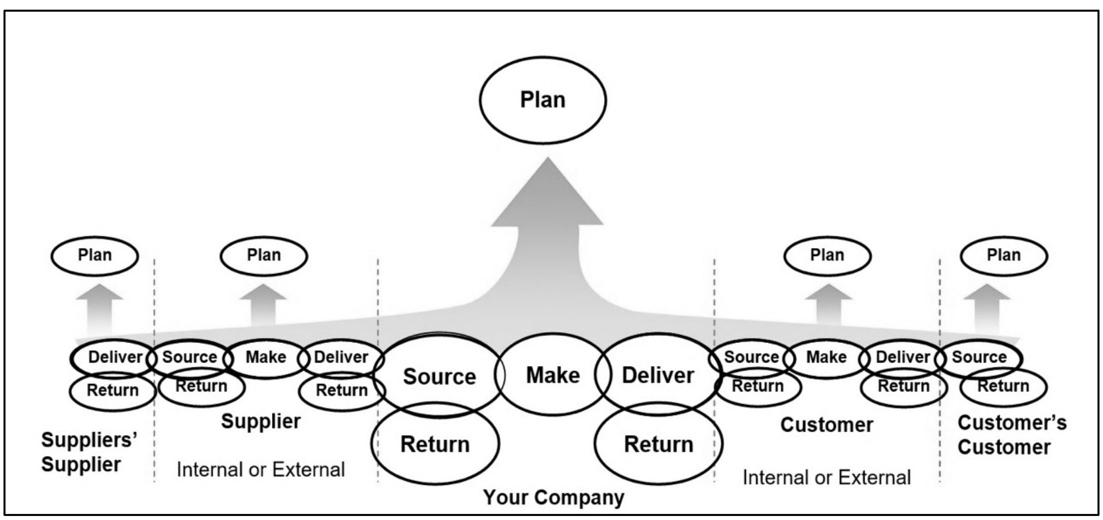

Figure 17. Level One SCOR 5.0 (Reproduced from SSC, 2001)

Throughout the 25 plus years of SCOR's existence, the model has undergone refinements and adjustments to keep the model current and relevant. The model continues to be updated and used by academics as well as supply chain practitioners worldwide. The latest version of the model has been revised and updated to reflect the technological changes enabling digital supply chains.

SCOR 12.0 Overview

The SCOR model is different from many other process models in that it integrates processes, metrics, practices, and skills into a single framework. The processes are organized in a hierarchy of six level one processes: *plan*, *source*, *sale*, *deliver*, *return*, and *enable*.

These processes are then decomposed into level two configuration processes such as *make to stock*, *make to order*, and *engineer to order* for the execution processes of *source*, *make* and *deliver* (Figure 18). Systemic processes have been established that detail the steps needed to execute level two configuration processes. For example, the process type *plan* is composed of five configuration level processes for *plan supply chain*, *plan source*, *plan make*, *plan deliver*, and *plan return*. Each of these level two processes is further decomposed into level three processes. This breakdown structure makes the model suitable for developing an ontology since it is already structured in a lightweight ontology format.

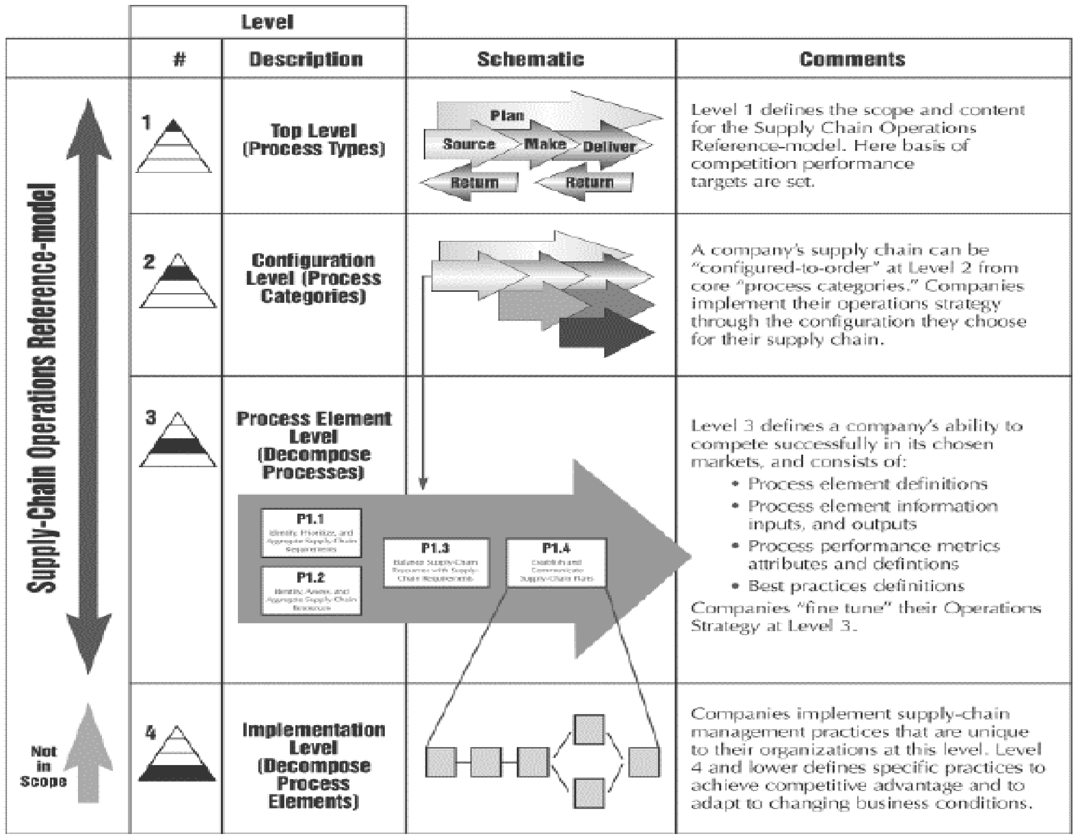

Figure 18. SCOR Level Taxonomy (Reproduced from ASCM, 2019)

Each level three planning process follows a standard configuration that involves identifying the demand/requirement and current resources and, before a plan is communicated, balancing resources and demand. The process definitions, and the inputs/outputs differ at this level, as processes are linked with inputs/outputs and several additional recommendations are made: a set of metrics to measure the process execution, best practices for process improvement, and defined skill sets needed to execute processes. The level four processes are the firm's processes that link to the SCOR level three's (Figure 19). This enables any supply chain to be mapped to SCOR processes and understood in more generic terms.

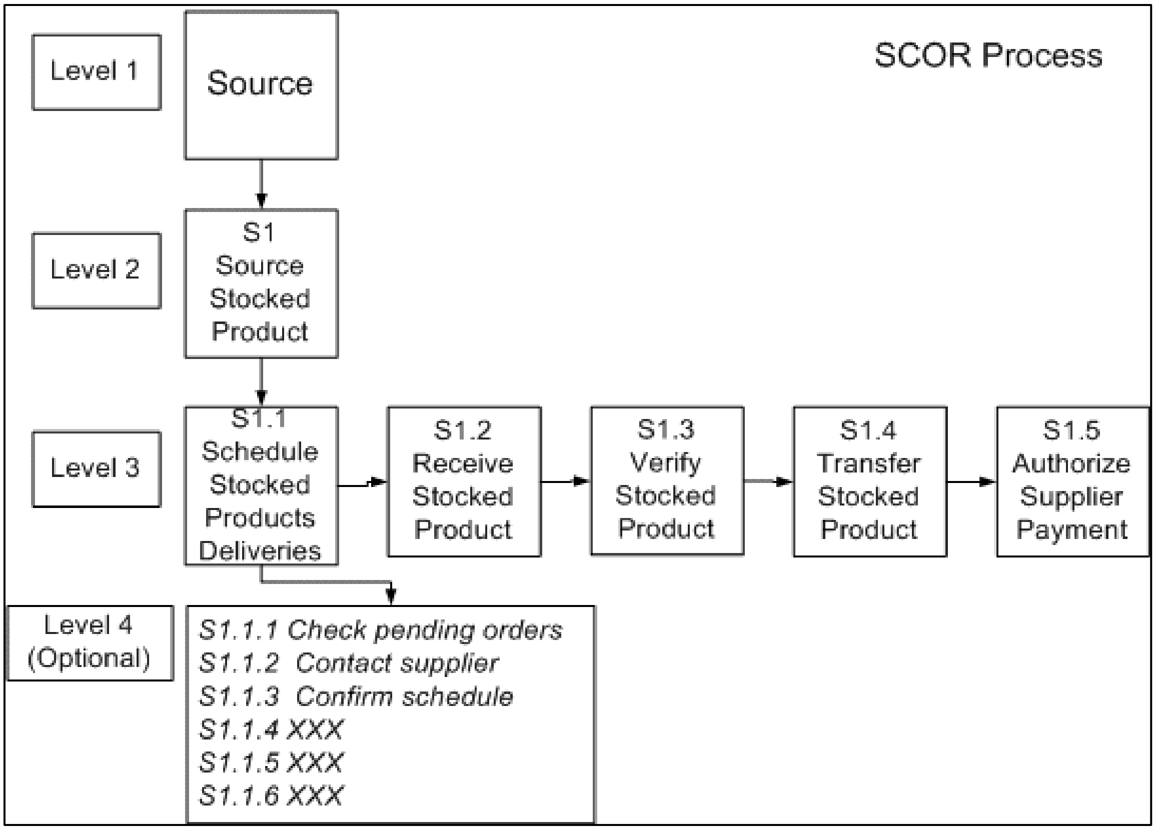

Figure 19. Example of SCOR Taxonomy Breakdown for Source (Reproduced from SCC,2010)

SCOR incorporates a numbering system that identifies processes and metrics as shown in Figure 18 above. Level one processes, for example, are identified with a lowercase "s," which means that the process is in the SCOR domain. This is followed by a single uppercase letter which stands for specific level one processes: P for *plan*, S for *source*, M for *make*, D for *deliver,* R for *return*, and E for *enable*. Level two processes are then identified by an additional numeric value. For example, the level two execution processes, *make to stock*, *make to order*, and *engineer to order* are identified with the addition of the numbers 1, 2, and 3, respectively. To illustrate, the *make to stock* level two execution processes are identified as sS1, sM1, and sD1. The process types *make to order* and *engineer to order* ETO follow the same logic.

However, the level two processes for *plan, returns*, and *enable* follow a different configuration breakdown. For example, *plan supply chain* is identified as sP1, *plan source* as sP2, *plan make* as sP3, *plan deliver* as sP4, and *plan returns* as sP5. The respective level two processes are linked to level three processes, at which level links between process steps are made (Figure 19). In contrast, level four processes are not defined by the SCOR model but are represented by the given organization's supply chain.

It is important not to confuse this breakdown structure with the metrics level structure. Furthermore, level one metrics are not designed to measure level one processes or level three metrics that are linked exclusively to level three processes. Level one metrics are key performance indicators (KPI), while level two and level three metrics are designed to break the KPI into parts and to support root cause analysis (Figure 20). It is also interesting to note that DuPont developed this metric numbering system to help their Enterprise Resource Planning (ERP) system.

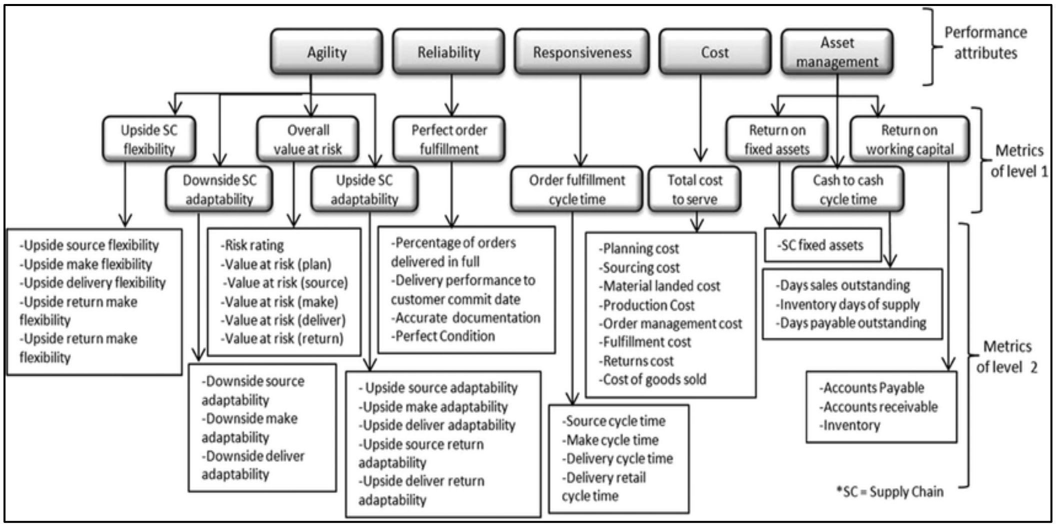

Figure 20. SCOR Metrics Tiered Structure (Reproduced from SCC, 2009)

The KPIs are broken down by key performance attributes that measure customer support or internal operations (Figure 21). The attributes of *reliability*, *responsiveness*, and *agility* regard how well the supply chain supports the customers, whereas the attributes of *cost* and *asset management* consider the supply chain’s organizational execution and efficiency. For example, reliability is measured by the indicator *perfect order fulfillment*, and the attribute responsiveness is measured by the indicator *order fulfillment cycle time*.

Figure 21 shows how the SCOR model is expanded and integrated with other organizational functions that support supply chain operations. The Design Chain Operations Reference model (DCOR) establishes hierarchical processes that define steps for developing and updating a product or service before execution. Next, the Customer Chain Operations Reference model (CCOR) addresses the processes needed to interact with customers. These processes include customer service, sales, and other related processes. Further, the Product Lifecycle Chain Operations

Reference model (PLCOR) addresses those business processes that manage the lifecycle of a given organization's products or services. Finally, the latest model developed, Manage for Supply Chain (M4SC; not shown) addresses the need for a strategic approach to designing a supply chain. These additional frameworks have been linked to the SCOR model, providing a much richer and more complete representation of an organization.

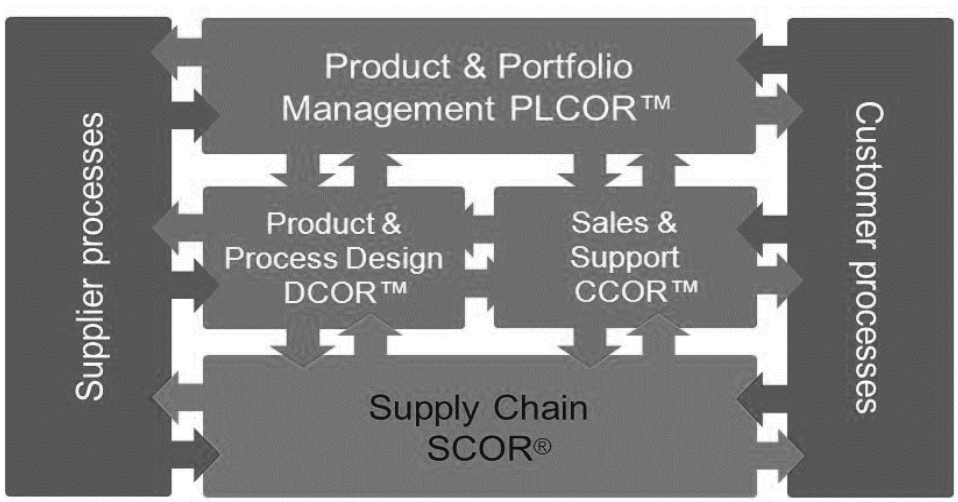

Figure 21. Other Frameworks (Reproduced from ASCM, 2019)

Since the merger of APICS and the Supply Chain Council (SCC), the SCOR model has undergone its latest update. Now SCOR 12.0, this latest model has been updated to align terms and definitions with the APICS dictionary and standards with the Global Reporting Initiative. Other updates include corrected modeling issues, revised best practices, updated metrics, and added enabling processes for procurement and for managing supply chain technology.

While SCOR 12 has attempted to standardize many of the terms and definitions used, much work remains to evolve the model into a basic formal supply chain ontology. The model was recently updated to include a digital supply chain information model; however, these were in the form of emerging practices and not developed to the extent needed for a formal ontology.

However, there appears to be enough content to select SCOR 12.0 as the basis for developing a basic formal supply chain ontology. This fact informs the scope of this research to create a set of refined research questions and establish a set of knowledge questions (step 4 of the Design Science Research Cycle; Dresch et al., 2015).

Based on this analysis, it can be concluded that this research development effort aligns with the Design Science Research (DSR) 15-step process outlined earlier in this section, specifically, step 5: Determine whether the research is within the design science paradigm. Since both information technology and the semantic web are artificial, this research fits the design science paradigm. Moreover, the basic formal supply chain ontology, as well as supply chains in general, are also artificial, despite similarities with naturally occurring models such as food chains.

Step 6 of the 15-step DSR methodology asks what the research will contribute to the knowledge of SCM. The contribution of this research to the supply chain knowledge domain is a common supply chain language and improved integration between supply chain partners. It is also envisioned that the development of a basic formal supply chain ontology would enhance knowledge and research sharing similar to that experienced by the Bio-Medical domain (Arp et al., 2015). Although step 7 has mostly been completed by defining the research topic, it is recommended that as the research progresses, the research and knowledge questions are revisited and revised when needed. Heretofore, the requirement has been to develop a basic formal supply chain ontology, although it might be necessary to refine this requirement (step 8) when warranted.

Step 9, the analysis of alternative solutions, has been partially completed with the review of other supply chain models. Additional analysis and research should be conducted on other IT integration tools and techniques to ensure that new and better approaches do not overcome the proposed solution. This step is in conjunction with step 10: Explore existing knowledge on alternative solutions. This prepares us to proceed to step 11; Prepare for development and evaluation. More will be presented on this step in the next section of this paper.

Methodologies for Developing a Basic Formal Ontology

Step 12, the construction or development of the basic formal ontology represents a crucial step. While some of the technical architectural information for developing a basic formal ontology was presented above in the section titled Requirements for Developing a Basic Formal Ontology, it addressed only what was needed and not how these elements could be developed. Three different approaches methods for developing a basic formal ontology are presented next.

The SCOR model represents a lightweight ontology in that it has a work breakdown structure of the generic processes carried out in a supply chain. According to IDEFO (Icam DEFinition for Function Modeling) standards, it has inputs, outputs, and activities. This proves useful in understanding the essential elements needed to develop a machine-readable basic formal ontology by supplying the needed triplets: subject, object, and predicate.

Additionally, the SCOR 12.0 model has directories for *practices* and *skills*. These two aspects of the model are also valuable to supply chain practitioners as they provide possible opportunities to improve processes and could potentially be used to develop an Artifical Intelligence system to propose solutions.

Just as there is no one way to build an ontology, there is no one tool. For the purposes of building this ontology, three different approaches are reviewed for comparison.

The first approach would be to code the model information directly into OWL. While this approach is theoretically cleaner, OWL coding is not easily read by human supply chain experts, and it is not as user friendly (Figure 22). Problems and issues with model rendering are not as easily identified, resulting in potential errors in the model that might not be discovered until much later.

```
<owl:ObjectProperty
rdf:ID="CT_MEASURED_BY2613">
    <rdfs:range
rdf:resource="#OT_KPIMake_Cycle_Time"/>
    <rdfs:domain
rdf:resource="#OT_FUNCMake_to__Stock"/>
  </owl:ObjectProperty>
<owl:ObjectProperty
rdf:ID="CT_IS_NEEDED_BY2986">
    <rdfs:domain
rdf:resource="#OT_KNWLDG_Lean_Manufacturing"/>
    <rdfs:range
rdf:resource="#OT_FUNCMake_to__Stock"/>
  </owl:ObjectProperty>
```

Figure 22. Sample of SCOR OWL Coding

A second approach would be to translate the existing SCOR model from the ARIS software (Figure 23) into an XML format before importing it into an OWL-based ontology (Botta-Genoulaz et al., 2006). Although this approach results in less coding, it is dependent on having SCOR 12.0 already loaded into ARIS. In addition, there is the need to understand both ARIS and OWL software. Although the ARIS/SCOR model views provide a readable display, it is difficult to review the XML translation and the resulting OWL model coding. This method was used only once for developing a SCOR 6.0 based ontology (Botta-Genoulaz et al., 2006).

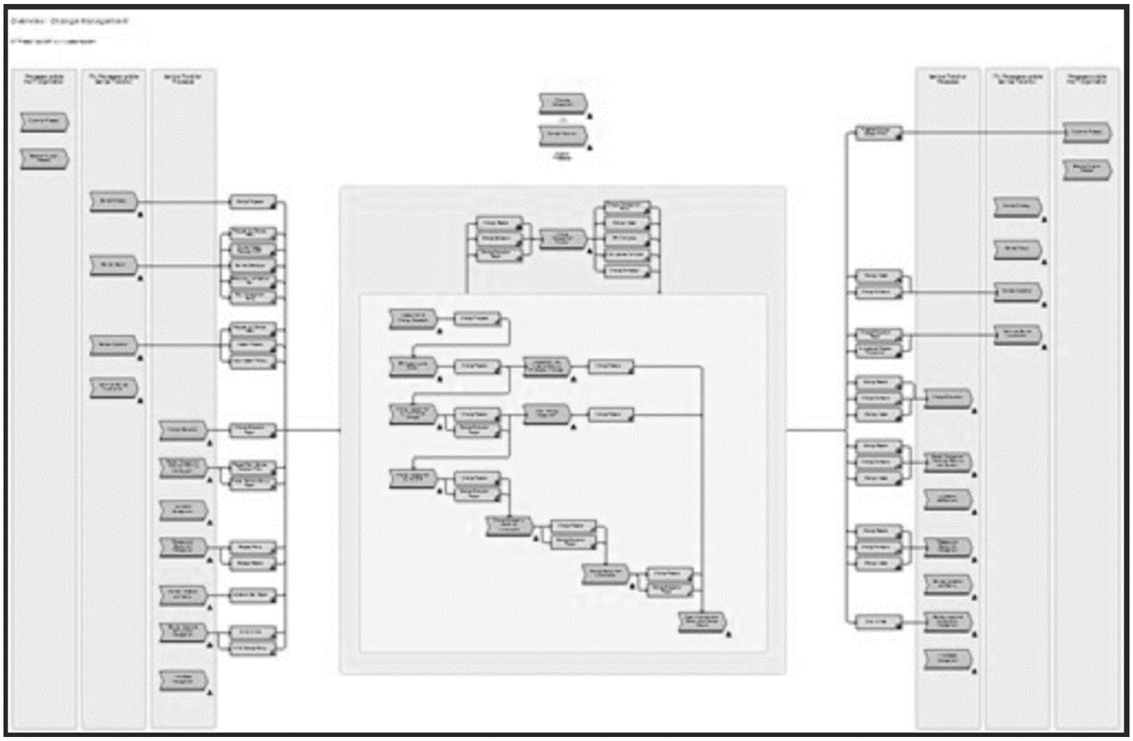

Figure 23. Example of SCOR Framework Mapping in ARIS

The third approach would be to simply input the model into Protégé software (Musen, 2015). This approach has the advantage that Protégé allows the software to model the framework and can produce several different machine-readable versions; for example, Resource Description Framework Schema or RDFS, XML, and OWL. This results in a more direct input of the model from the print version of SCOR without an added layer of additional translation. In addition, the Protégé data entry and display is much more understandable by modelers and users than the OWL code.

Another essential feature of this approach is that the software includes several different add-on software applications and features that can be used to further enhance and test the model. For example, by inputting aspects of the knowledge domain to be modeled, the software can infer an ontology structure. This can be a useful application if a structure remains undefined for the knowledge domain. When developing a SCOR 12 ontology, however, it was decided to assert the structure since the print version of the model is already in work breakdown structure.

Once the SCOR Ontology has been developed, step 13 of the 15-step DSR methodology is designed to test or evaluate the ontology in an artificial environment prior to testing it in a natural or real environment. This is accomplished in Protégé using a software capability called Reasoner. This capability will evaluate the SCOR ontology for logical errors that may be in the developed ontology. For example, *Source* processes not modeled in *Make* processes or in *Metrics*. Furthermore, Reasoner tests to verify that there is a relational structure of the model. Finally, in the case of two classes, Reasoner verifies that one class is subsumed by the other. To illustrate, in the case of *Make* and *Make to Stock*, *Make to Stock* is subsumed by *Make*. In conclusion, Reasoner fulfills the need to test the model for logical soundness in an artificial environment.

This approach provides specific test findings and a deeper understanding of the importance of information exchanges within the supply chain. Finally, these findings should provide an improved understanding of digital supply chains' designs and the importance of a standardized model and supply chain language.

The Protégé software has been used successfully in many ontology developments and is supported by a robust user group. In addition, Protégé was developed and is maintained by ontology experts from Stanford University with no cost for use of the software; only a citation is required.

If the SCOR ontology passes the test in the artificial environment it will be necessary to test it in a natural or live supply chain to ensure that it works as intended. Step 14 is designed to *test drive* the ontology on a real supply chain; however, this can be accomplished only in a test environment that is designed to mirror the actual digital application before going live in an actual supply chain. This is done to ensure that the model is working correctly before using it on actual supply chain transactions when success is required due to actual costs being incurred. Due to the COVID-19 pandemic this test weas not conducted. Individuals who were to be involved in the testing were working from home with limited connectivity.

Finally, step 15 is to communicate the results of the research. This step is designed to publish the research in scholarly journals, but also to ensure that the results and findings are presented to supply chain practitioners who can then apply it.

Developing a Supply Chain Ontology Based on SCOR 12.0

The development of a supply chain ontology using the SCOR 12.0 model applies the design science methodology outlined by Alturki et al. (2011). The framework for this development effort uses a rigorous 15-step research methodology. The 15-step process is as follows:

1. Document the idea or problem to be studied.
2. Investigate and evaluate the importance of the problem or idea.
3. Evaluate the new solution feasibility.
4. Define the research scope.
5. Define if research is within the design science methodology.
6. Establish type of research contribution.
7. Define topic/subject (construct, evaluation, or both).
8. Define requirements.
9. Define an alternative solution to the problem.
10. Explore existing knowledge to support the proposed alternative.
11. Prepare for development and evaluation.
12. Construct (development) new artifact.
13. Evaluation (artificial evaluation) of artifact.
14. Evaluation (naturalistic evaluation) of artifact.
15. Communicate results.

Although some of these steps have been addressed earlier in this paper, they are briefly presented here to maintain the flow for this development/research effort.

Document the Idea or Problem to be Studied

Information is a fundamental part of any supply chain, and it is becoming even more important with the growth of digital supply chains. Digital supply chains use information technology to automate and accelerate actions such as planning, replanning, ordering, shipment tracking, and many other activities. To ensure these automated activities occur as intended, many researchers and industry leaders see the need for a standardized language for supply chain management. Because of the increased importance of technology, the language must be computer-readable. This calls for developing an ontology designed to organize and define key supply chain definitions and processes understood by humans and computers across the supply chain.

Investigate and Evaluate the Importance of the Problem or Idea

Leveraging information technology has proved to be an advantage for organizations and their supply chains. Amazon, for example, has taken information technology to a new level of competition by making decisions quicker, automating the ordering process, and lowering their cost of doing business. Most supply chains would benefit from using technology to lower costs and improve information processing to improve operations.

Evaluate the New Solution Feasibility

Ontologies organize domain specific information by providing structure and standardized terms and definitions that aid in communication and improve understanding. For example, ontologies have been used to organize and standardize the vast information generated by biological and medical research. This has led to improved communication, enhanced knowledge sharing, and facilitated a greater understanding of the biological and medical domain (Arp et al., 2015). The development of a common supply chain ontology has been the subject of many studies, the majority of them using the SCOR model as a starting point for development. The reasons for using the SCOR framework is that it has an integrated set of processes and metrics understood by most supply chain professionals, and it is already in a work breakdown structure. The framework also includes supply chain skills and practices that are designed to improve process performance. This results in a complete model that can be applied to any type of supply chain. Finally, the SCOR model is widely recognized and used by global supply chains, which increases the likelihood of the ontology being adopted.

Define the Research Scope

This research focuses on using the SCOR 12.0 model as the basis for developing an ontology for supply chain management, which can then be used to produce a Web Ontology Language (OWL) model suitable to information technology (Arp et al., 2015). The World Wide Web Consortium developed OWL as an open standard for anyone interested in creating a basic formal ontology. OWL is an essential part of the *technology stack* instrumental to the interoperability of information and data on the web. Other SCOR-based ontologies have been developed, but they are based on older versions of the SCOR model (versions 6.0, 9.0, and 11). These older versions of SCOR do not represent the current technologies and processes used by many leading supply chains. In contrast, the SCOR 12.0 ontology will be comprehensively developed down to the level three classes defined in the SCOR 12.0 model.

Define Whether Research is Within the Design Science Methodology

Supply chains are an artificial representation of a naturally occurring phenomenon that is more aligned with design science. This research resists optimizing supply chain management in theory, focusing instead on the development of an ontology that can be implemented and understood globally by most supply chain professionals.

Establish Type of Research Contribution

The SCOR 12.0 based ontology developed in this research includes new processes that capture improvements in the procurement process as well as techniques for managing supply chain technologies. Also, SCOR 12.0 incorporates many new and emerging technologies such as cloud computing, big data, artificial intelligence, and the internet of things (IoT), key enablers of digital supply chain transformations (Siebel, 2019). This research presents an ontology of crucial supply chain terms, definitions, and processes aligned to traditional and digital supply chains. Finally, this research also provides supply chain practitioners and researchers with a basic formal ontology to improve understanding of supply chains and their operations.

Define Topic/Subject (Construct, Evaluation, or Both)

The objective in conducting this research is to construct a basic formal supply chain ontology based on the SCOR 12.0 model. Although this research includes evaluating other supply chain models, it does so only to identify the best candidate for developing a supply chain ontology.

Define Requirements

This research requires an understanding of supply chain management, trends, and possible future developments. Also required is an understanding of information technology as related to ontologies, OWL, supply chain information flows, and finally, an understanding of SCOR 12.0. Presented separately, these intertwined requirements aid in the knowledge of the ontology development process.

Define an Alternative Solution to the Problem

Other frameworks were reviewed as possible alternative solutions to develop an ontology. Although each framework shows unique capabilities, they are incomplete when compared to SCOR 12.0. Finally, the frameworks are less understood than SCOR.

Explore Existing Knowledge to Support the Proposed Alternative

There is significant academic and industry support for developing an ontology by leveraging an existing theoretical or industry model. This approach closely aligns with the actual processes being modeled for the supply chain domain and enables faster adaptation (Arp et al., 2015). Use of the SCOR model as a starting point is documented in the Methodology chapter under the section entitled *SCOR as a Suitable Starting Point.*

Prepare for Development and Evaluation

This research shows that there are several ways to develop an ontology. One method involves coding the ontology into the Web Ontology Language (Lacy, 2005). Another approach is to export the SCOR model from an ARIS software version of the model using XML and then translate it into OWL. However, there is considerable risk to each of these methods due to the translations and the limited number of supporting analysis tools available. The selected approach is to translate the SCOR 12.0 model into OWL via Protégé 5.0. Protégé, a free software developed and maintained by Stanford University that is widely used to build ontologies. The software is supported by several add-on tools that assist in the development and analysis of ontologies, such as Reasoner. This tool analyzes the ontology to ensure that it does not violate any logic construct. The tool can also infer an ontology basis of the information supplied (Musen 2015).

Construct (Development)

Because the SCOR 12.0 model is already organized in a work breakdown structure (Figure 24), using this structure allows it to be modeled into Protégé. Asserting the model in this way allows for greater control over how the model is represented, ensuring that it is human readable once in Protégé. This approach also reduces the risks of unseen errors due to dealing with a computer-generated model or one inferred by Protégé. Asserting the model into Protégé ensures that it is readable by practitioners (Figure 25) as well as computers (Figure 26).

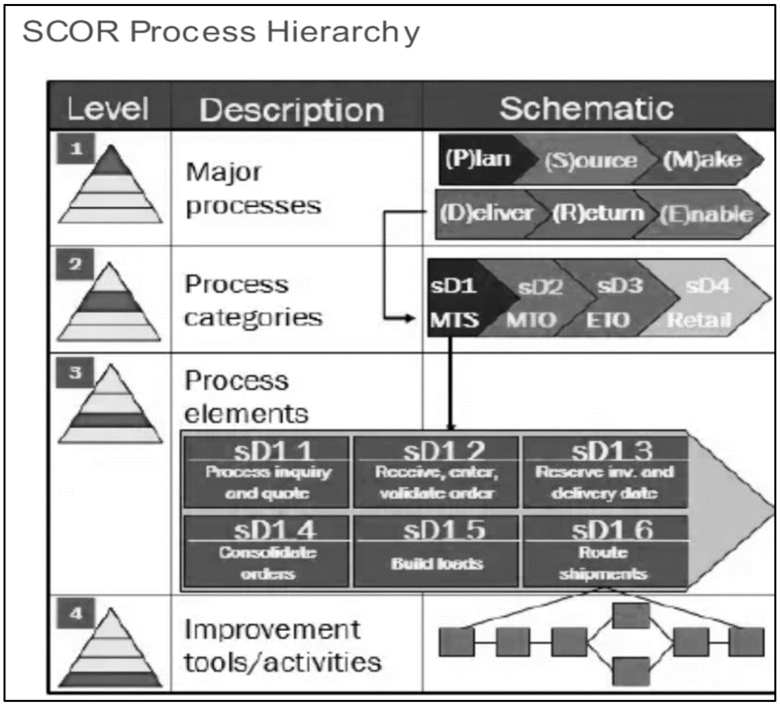

Figure 24. SCOR Process Hierarchy (Reproduced from ASCM, 2019)

Figure 25. SCOR Process Hierarchy in Protégé

```
File Edit Format View Help
<?xml version="1.0"?>
<Ontology xmlns="http://www.w3.org/2002/07/owl#"
     xml:base="http://www.semanticweb.org/david/ontologies/2020/9/untitled-ontology-5"
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
     xmlns:xml="http://www.w3.org/XML/1998/namespace"
     xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
     ontologyIRI="http://www.semanticweb.org/david/ontologies/2020/9/untitled-ontology-5">
    <Prefix name="" IRI="http://www.semanticweb.org/david/ontologies/2020/9/untitled-ontology-5"/>
    <Prefix name="owl" IRI="http://www.w3.org/2002/07/owl#"/>
    <Prefix name="rdf" IRI="http://www.w3.org/1999/02/22-rdf-syntax-ns#"/>
    <Prefix name="xml" IRI="http://www.w3.org/XML/1998/namespace"/>
    <Prefix name="xsd" IRI="http://www.w3.org/2001/XMLSchema#"/>
    <Prefix name="rdfs" IRI="http://www.w3.org/2000/01/rdf-schema#"/>
    <Annotation>
```

Figure 26. OWL coding for SCOR Ontology

The SCOR model has four main sections: performance, processes, practices, and people (Figure 27). These main sections of the model are linked to the processes and are used as the primary sections or classes for the Protégé ontology (Figure 28).

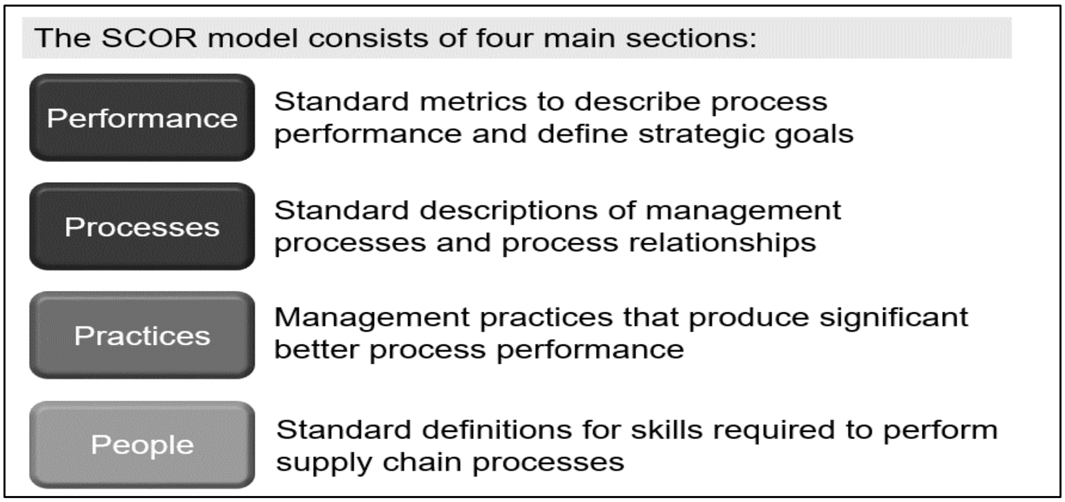

Figure 27. SCOR Four Main Sections (Reproduced from ASCM, 2019)

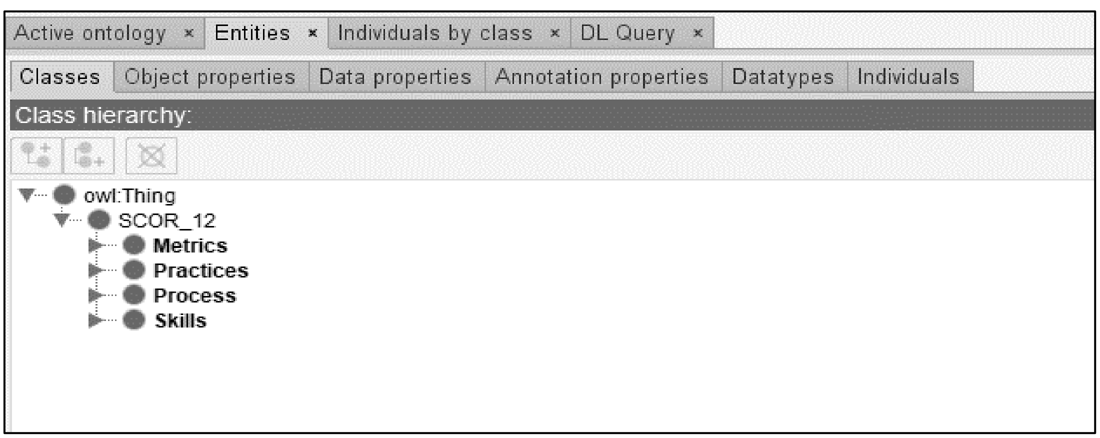

Figure 28. SCOR 12.0 Construct in Protégé Classes

Each of the upper level Protégé classes is then further broken down into level one classes, as shown in Figure 29. The generic class of processes are then decomposed into the SCOR level one processes of *plan*, *source*, *make*, *deliver, returns*, and *enable*. The SCOR metrics are also decomposed based on the key performance attributes of *agility, asset, cost, reliability,* and *responsiveness*.

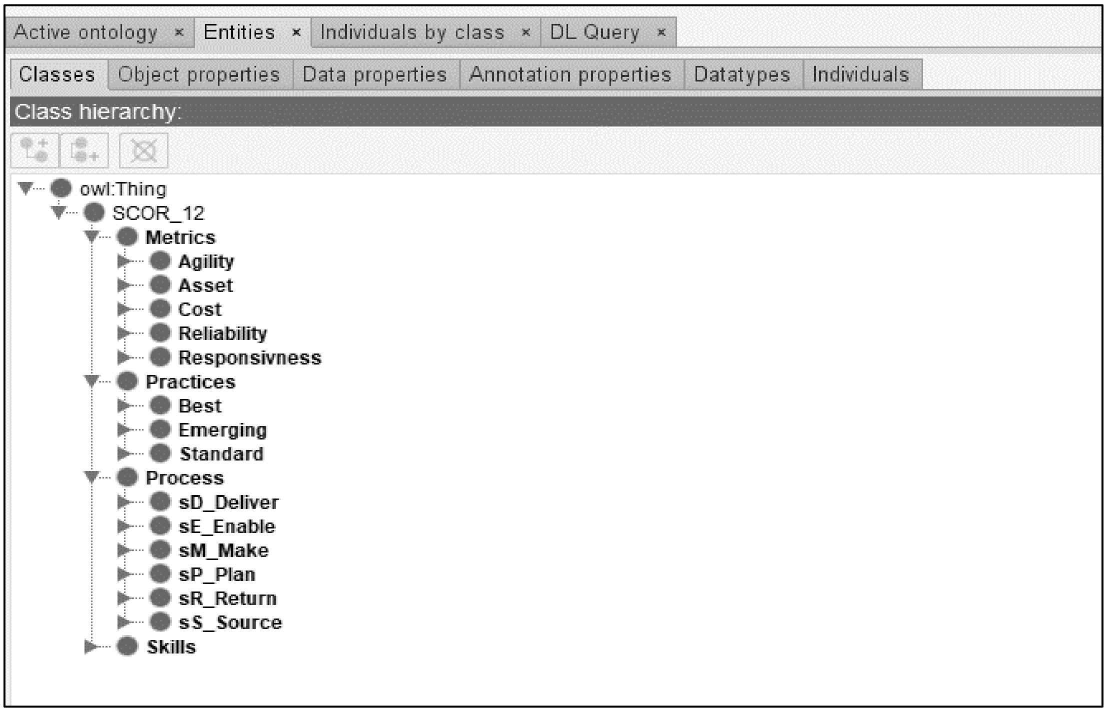

Figure 29. SCOR 12.0 Classes for metrics, processes, and practices

The SCOR practices are also divided into subclasses of *emerging*, *best*, and *standard*. Finally, the *people* or *skill* portion of the model has no lower-level classifications. Whereas these classifications further our understanding of supply chain management and the SCOR model, the SCOR processes form the integration point for metrics, practices and skills. For example, SCOR processes are measured and monitored by metrics.

The level one processes of *plan*, *source*, *make*, *deliver*, *return*, and *enable* consist of level two subclassifications; however, these subclasses differ from the level one processes. For example, the *plan* process is further divided into *plan supply chain, plan source, plan make, plan deliver,* and *plan return* (Figure 30) to capture the planning for each of the individual processes. Likewise, *source*, *make*, and *deliver* contain the level two sub-classes *make to stock*, *make to order*, and *engineer to order*. Further, the *return* process contains the subclasses *deliver returns* (customer returns) and *source returns* (returns to suppliers). Finally, the subclasses for the enabler process manage business rules, performance, data and information, human resources, assets, contracts, network, regulatory compliance, risk, procurement, and technology. Each of these level two classifications is further decomposed into level three process classes.

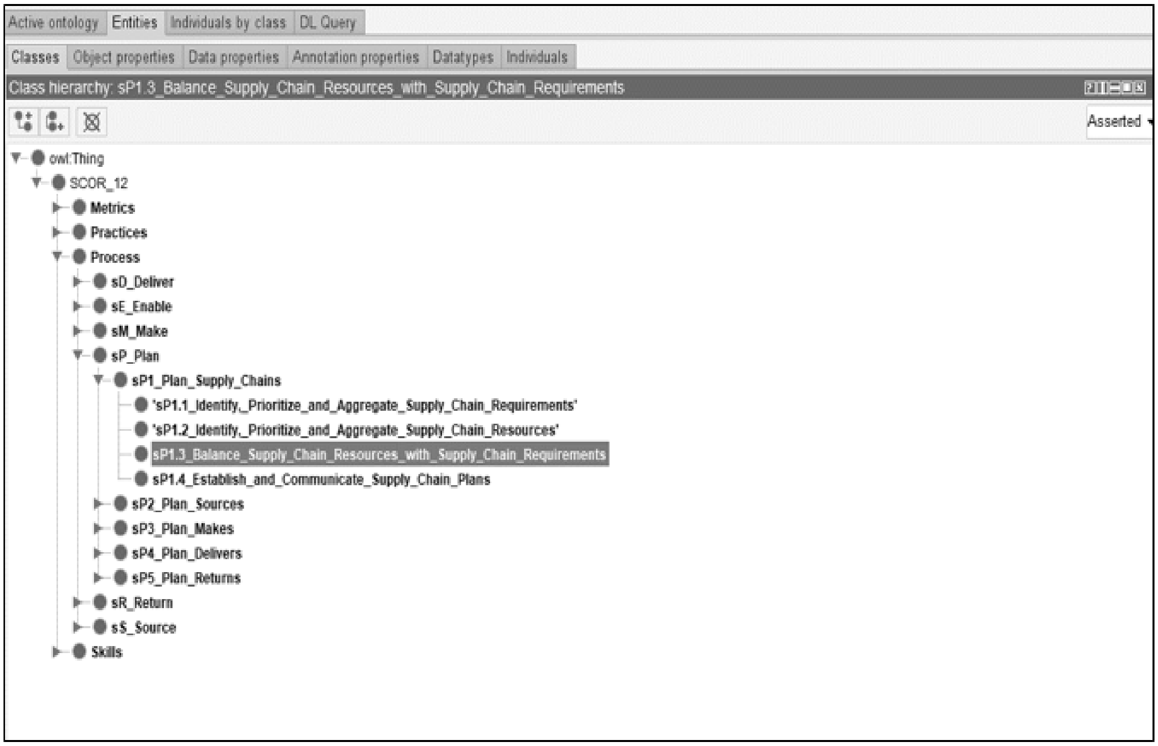

Figure 30. Example of Level Three Processes for *Plan* Supply Chain

The level three processes document input and output and link *metrics, practices,* and *skills*. This aspect of the model is fundamental to the ontology's representation. It represents an essential vertical link to the supply chain domain structure and provides a horizontal integration point for the ontology. This horizontal integration of the model provides the most logical subject-predicate-object representation covered later in this chapter.

Level one SCOR metrics measure level one KPIs and are supported by level two and three diagnostic metrics. These level two and three metrics are used to identify possible root causes of the process defect. There is alignment between the Key Performance Attributes and the KPIs and supporting Level two metrics in the model.

Although each level two metric is directly aligned with an individual KPI, level three metrics are often not. Furthermore, only some level three metrics are aligned with level two metrics. Where there is an alignment, it is captured in the ontology. Although there is no alignment for level three metrics, they are nevertheless classified as additional level three metrics, as shown in Figure 31. These additional level three metrics allow the supply chain manager to better understand a given performance attribute and KPI.

Figure 31. Example of Level Three Metrics alignment

The level two practices are classified as either *standard, best*, or *emerging*. Each of the individual practices is placed into one of three classes. The *Skills* practice, on the other hand, does not have a sub-division and is not further classified. A screenshot of a large section of the asserted SCOR model in Protégé is shown in Figure 32.

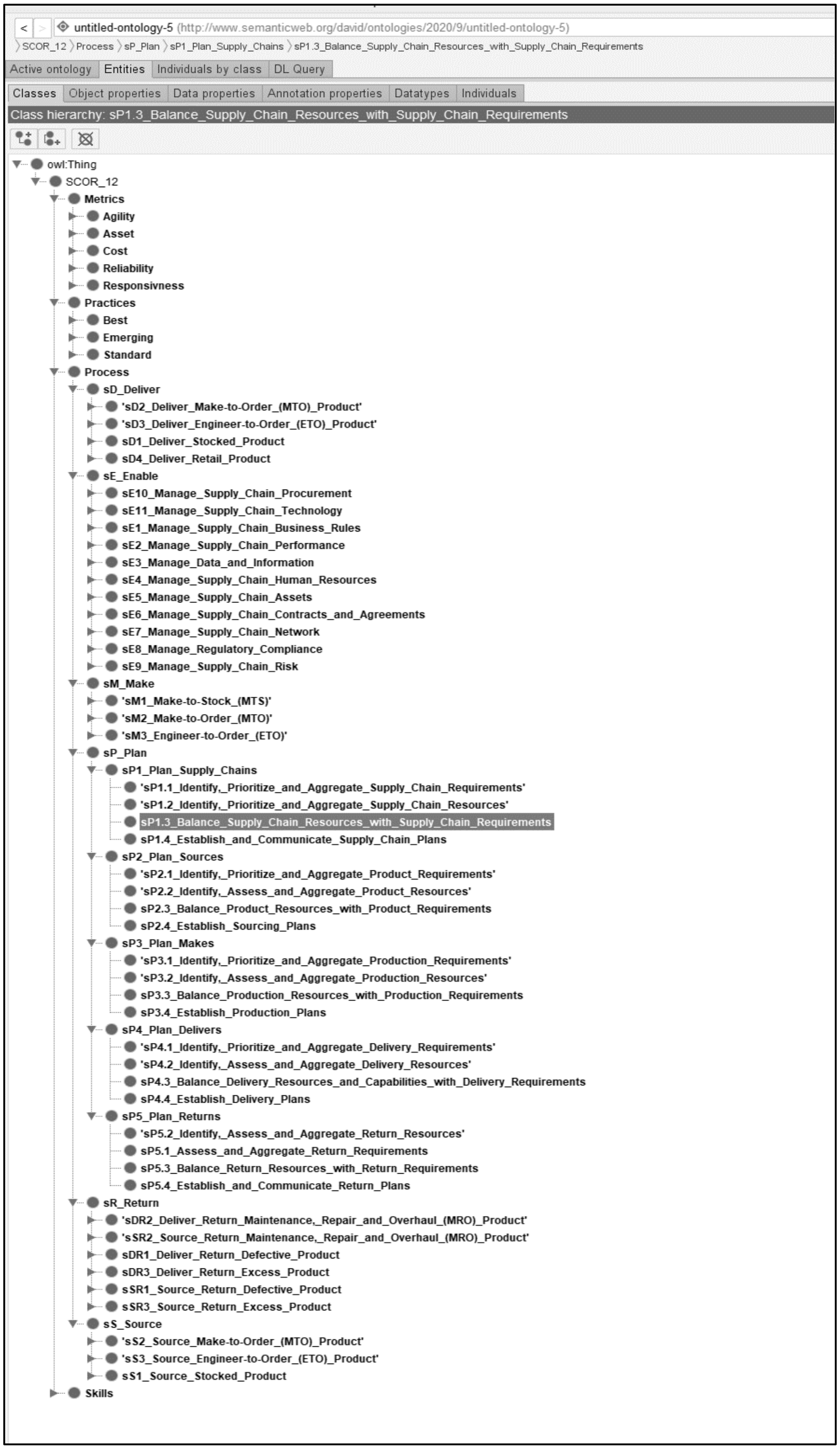

Figure 32. Example of the Asserted SCOR 12.0 Ontology

Once the basic ontology structure is asserted, each of the level two classifications is set as disjointed, meaning there is no overlap between the level two classes. This action is required since a fundamental assumption of OWL is that there is some level of overlap between different processes or classes within an ontology. Disjointing the SCOR ontology processes, metrics, and practices ensures that they are treated as separate and unique. This is especially important for the processes of *make to stock*, *make to order*, and *engineer to order* (Figure 33) as each relies on different information triggers to take action. For example, a project to build an engineer-to-order product requires a signed-off set of plans or communication of a similar obligation. Likewise, *make to stock* processes are triggered by inventory level, and if inventory falls below the desired stock level, more product is ordered or manufactured.

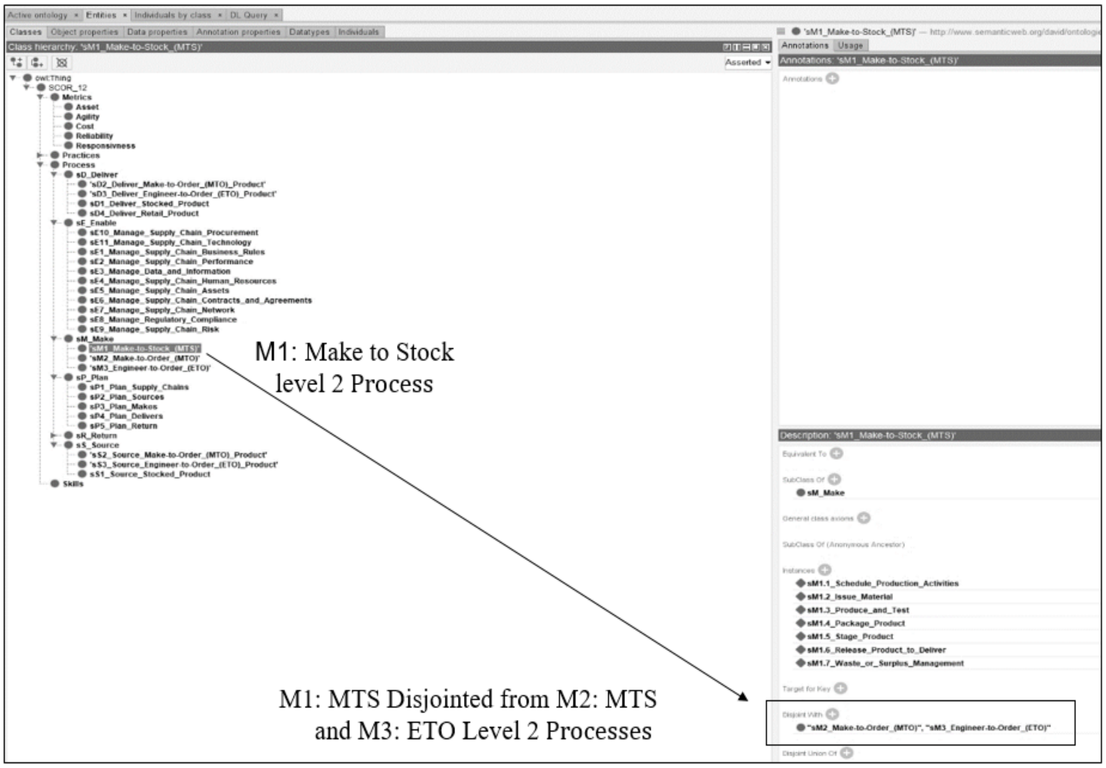

Figure 33. Example of Disjointed Classes for MTS from MTO and ETO

Similarly, the KPIs are also set to disjointed since each measures a different part of the supply chain performance. For example, the KPI *perfect order fulfilment* measures supply chain reliability and *cost* measures operational costs and the cost of goods sold. It is apparent that a change in one KPI, such as reliability, can affect another KPI, such as cost, although this interaction depends on the organization and industry. The result of disjointing these elements is a cleaner construct that aligns with the SCOR model and provides more explicit process signals, event and trigger definitions, and metric calculations.

Each of the processes, metrics, practices, and skills has a description that aids in its understanding. Figure 34 shows an example of a description included in the Protégé software via the annotation section. Sometimes this is a simple one-line definition and other times a paragraph with added explanations and calculations, as is the case with metrics. While developing the ontology, it is important to capture this information since it is added to the ontology as a knowledge domain representation.

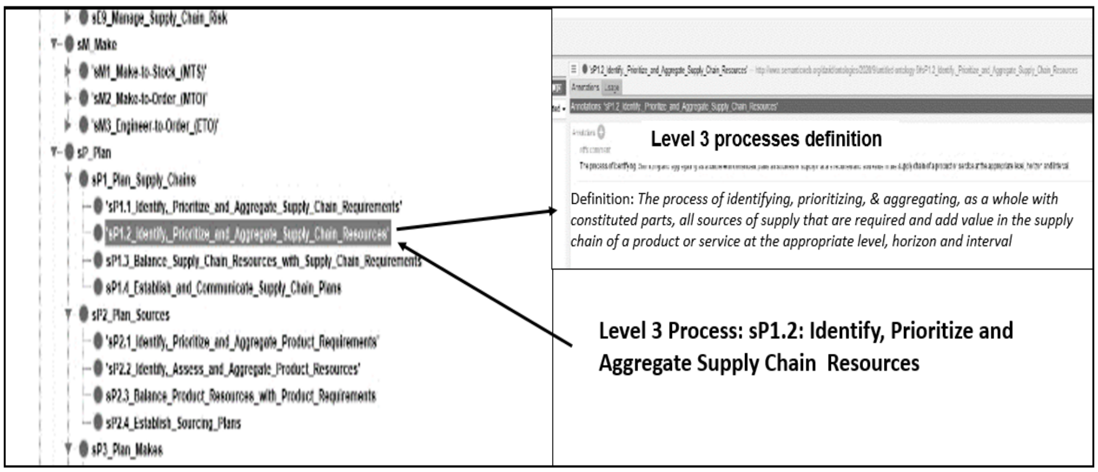

Figure 34. SCOR Process Definition via Protégé Annotation

The representation of SCOR model integration is a vital aspect of turning the SCOR taxonomy into a more robust ontology. This integration aligns with the vertical linkage of the processes and metrics from level one through three with the respective metrics, practices, skills, inputs, and outputs defined by the SCOR model. This is where an ontology's subject-predicate-object structure enriches the understanding of supply chains by showing integration between the vertical hierarchy and the horizontal integration.

The subject portion of this structure represents a given domain, as defined in Protégé, and the object represents the range. The predicate, or action, is what links the subject to the object. This linkage is found in Protégé via the object properties. Identifying the object properties at individual level three processes allow integration while maintaining the SCOR model's integrity. Modeling each of the four sections, process, metrics, practice, and skills enables this representation to be made. Further, the predicates are represented as *hasMetric*, *hasSkill*, *hasInput*, *hasOutput*, and *hasPractice.* Object properties identified in OWL always begin with a lower-case letter and contain no spaces. Each of these five predicates, *hasMetric*, *hasSkill*, *hasInput*, *hasOutput,* and *hasPractice*, is defined for each individual level three process. Figure 35 shows the *plan* supply chain level three processes of sP1.1, sP1.2, sP1.3, and sP1.4. In addition, Figure 36 shows the subject/domain and the corresponding objects/range as sP1.3 for the predicate *hasInput*. The actual received input is identified in the annotation section of the object property tab (Horridge 2011). This results in the 211 level three processes being used as object properties with five predicates for each, which brings it to a total of 1055 domain/range/predicate sets. As mentioned earlier, a supply chain's individual processes link at level three processes. This linkage then translates the unique supply chain process into a more standardized SCOR based definition.

Figure 35. Object Properties

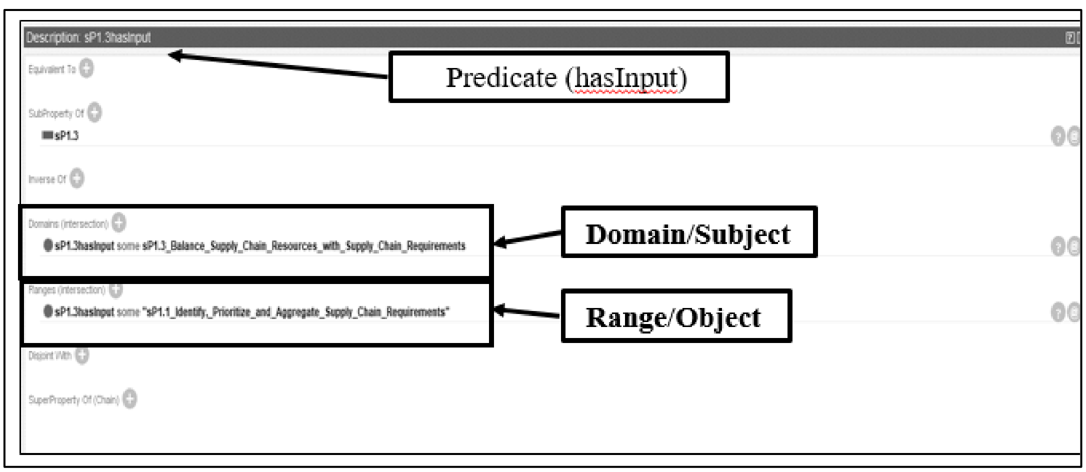

Figure 36. Object Property showing the Subject, Predict, and Object

In addition to object properties, Protégé has the capability to not only capture object properties, but also data properties. This Protégé capability is used to set data value types for the SCOR metrics shown in Figure 37. While data properties have a subject, the type of data selected can limit the value. For example, *Integer* selected in Protégé will only have whole number values, which differs from Decimals. For the most part, the Resource Description Framework (RDF) literal option is selected since this is the least restrictive.

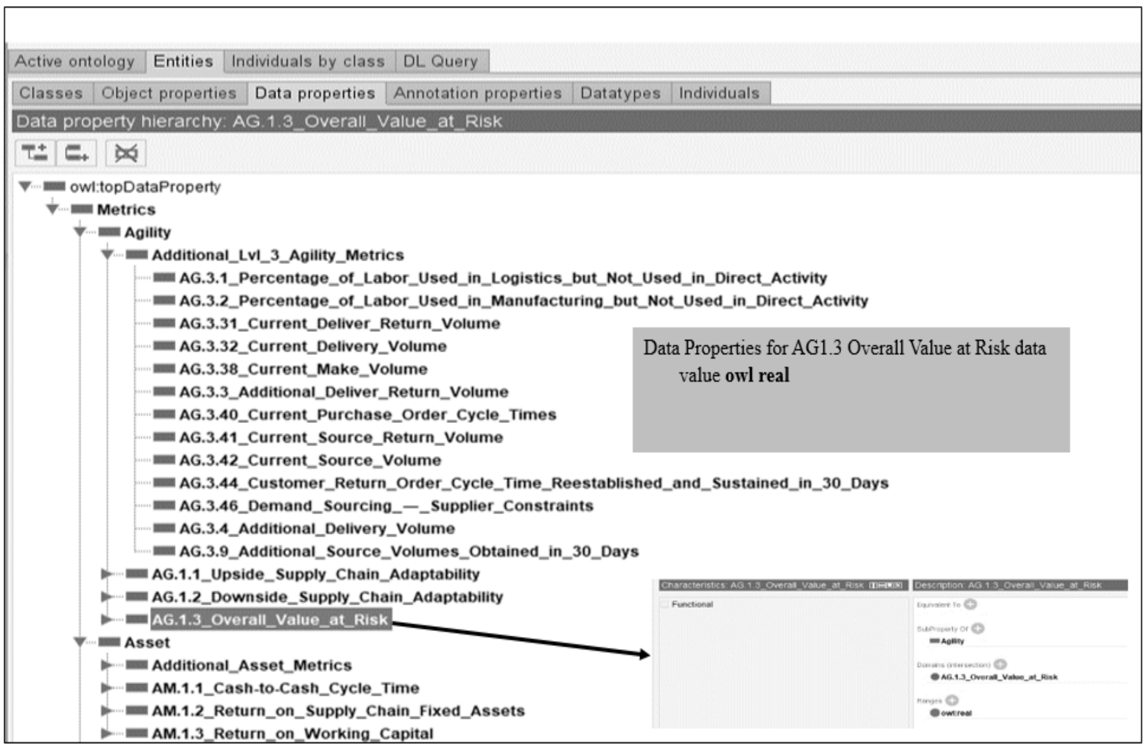

Figure 37. SCOR Data Properties for AG 1.3 Overall Value at Risk

The real benefit of using Protégé software to capture the SCOR 12.0 ontology is the ability to assert an ontology that can be understood by supply chain managers while still being able to generate information in RDFS, XML, or OWL. Maintaining a human-understood representation of the ontology makes the translation much more manageable. This is key as the model becomes increasingly more complex as more layers and integration points are added. Finally, Protégé software can run a check on the ontology via the Reasoner tool.

Evaluate (Artificial)

Reasoner is an application within the Protégé software set that checks the ontology logic for consistency and structure, which is used to test the SCOR 12.0 ontology. Figure 38 shows the configuration of Reasoner before running the check. Reasoner was used as an artificial validation and showed no issues with the asserted SCOR ontology. Specifically, no inferred ontologies are displayed, so the asserted SCOR 12.0 ontology passes the test. If any problems had been found, Reasoner would have presented the problem area(s) with a recommended or inferred solution: None were identified.

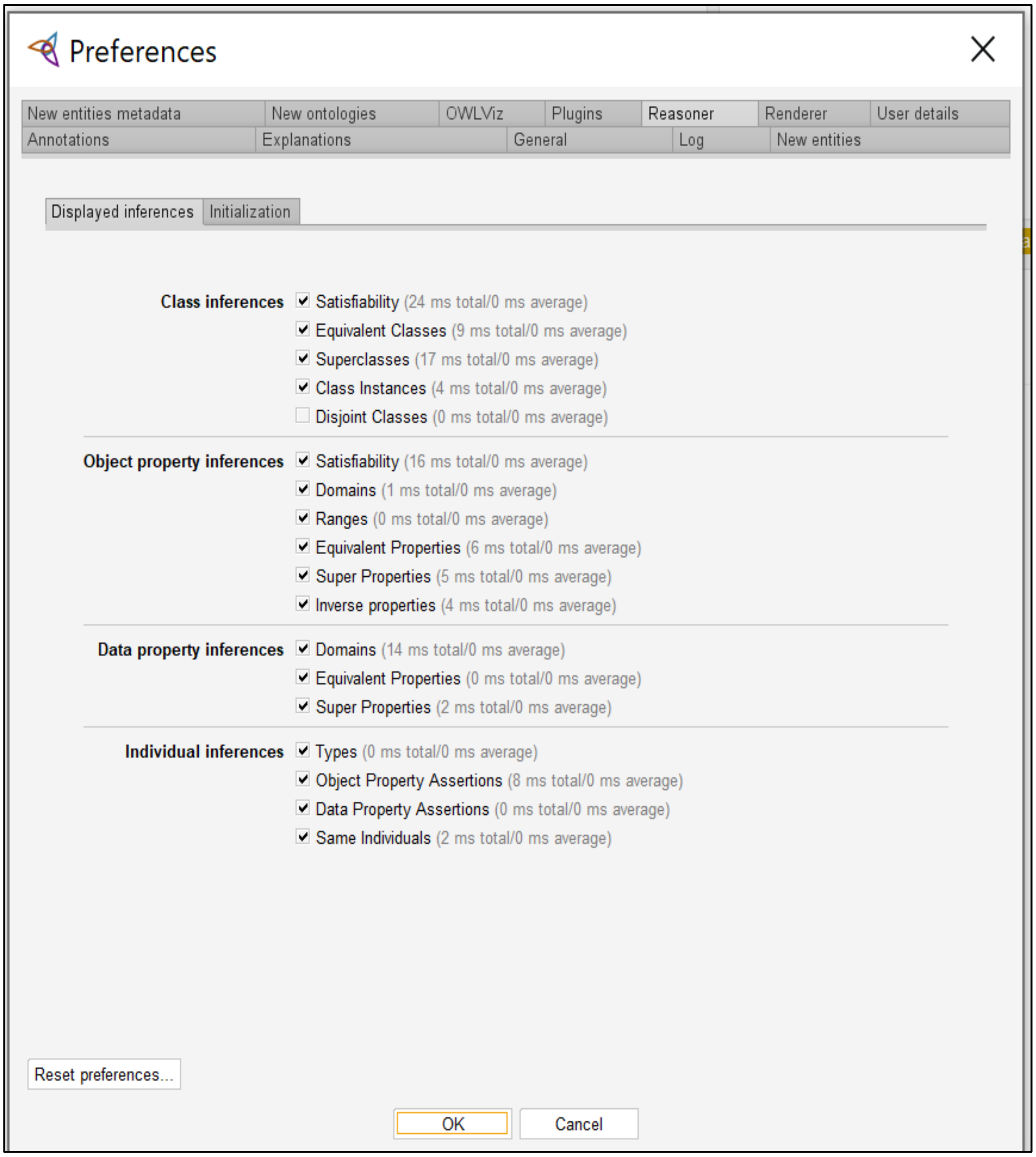

Figure 38. Reasoner Configuration Settings

Evaluate (Natural)

The second test could be conducted in a natural supply chain. While this evaluation was not conducted on the SCOR 12.0 ontology, two examples of how this evaluation could be accomplished are detailed in the Recommendations for Future Resesearch below.

Communicate the Results

The final step in the design science methodology is to communicate the results. Exposing the research and development effort to academic review by publishing the findings and the resulting supply chain ontology ensures that it has been conducted with sound logic and intellectual rigor. However, according to design science, findings should also be shared with practitioners who can use the findings.

Presenting the research and development to supply chain practitioners ensures that the supply chain ontology is practical for real-world supply chains, adding value by improving supply chain performance and enhanced interoperability. These findings will be presented at an Association of Supply Chain Management webinar in 2021. In addition, publications in a variety of supply chain focused journals, magazines and webstes will also be pursued to spread the word.

Conclusions and Potential Future Research

The need for a common language for supply chain management is an objective that has been sought by scholars and practitioners alike. This need becomes more pressing as supply chains become increasingly integrated and digital. A common language and model representation promises improved performance and interoperability. This research and development effort does not claim to meet this need entirely, but rather it builds on earlier works using the SCOR model for a supply chain ontology. This research also extends previous efforts by using SCOR 12.0, the latest version available for general use. SCOR 12.0 enhances the older versions of the SCOR model by including new processes and improvements that incorporate the latest technologies in leading digital supply chains.

This research identifies key elements required to develop a basic formal supply chain ontology (RQ1), which are then used to select the most appropriate supply chain model on which to base the ontology. The supply chain ontology is then developed using the design science research methodology (RQ2).

A possible next step based on this research would be the development of a logical data model using the SCOR 12.0 metrics and data elements. This has been a desired outcome of this research since it was first conceptualized; however, it is beyond the scope of this effort. The potential data model would be valuable to researchers and practitioners as it would further define supply chain data, improving communication and understanding.

The SCOR model focuses primarily on supply chain operations and not on the strategic aspect of supply chains. Prior to the merger with APICS, the Supply Chain

Council had begun developing a process model (M4SC) that translated a business strategy into a supply chain strategy. The M4SC would help ensure that the supply chain developed would support the business strategy. Completing the M4SC model would hold considerable value for organizations and supply chain operations by providing a process that ensures the development and implementation of the right supply chain to achieve purposes defined by the business strategy. Finally, M4SC could aid in determining where and when digital supply chain technology investments should be made.

. In prior years, the Supply Chain Council researched ways to improve integration with suppliers and customers. The council developed formal support operating models that focused on customers (CCOR), as well as suppliers and product development (DCOR). However, these processes have not been updated for several years. At the time of this writing, a leading consulting firm is attempting to establish these processes into a more cohesive digital supply chain model. The SCOR model currently lacks a focus on acquisition, and improvement is needed. The SCOR 12.0 model includes an enabler, *Manage Supply Chain Procurement* (sE10) that addresses this void, although it does so in a fragmented fashion. The enabler uses the Chartered Institute for Procurement and Supply's (CIPS) process model as a template to address deficiencies. While some of the CIPS processes are already in prior versions of the SCOR model many were included in SCOR 12.0. However, this has resulted in a fragmented representation of the entire acquisition process. A complete model needs to be developed for the acquisition/procurement process to define this supply chain activity. This effort is made even more crucial with the increasing importance of acquisitions.

Understanding supply chain management provides many benefits to organizations and society through improved availability of goods and services. In the early days of the COVID-19 pandemic, supply chains were discussed frequently in the media to explain the shortages of certain goods. Although the increased media attention on supply chains has been a good public introduction to this topic, its complexity is often explained in oversimplified ways. A goal of this research is to generate a greater understanding of complex supply chains by presenting a common model.

The use of the SCOR model has been well documented in many case studies and books. The Supply Chain Excellence books by Pete Bolstorff and Robert Rosenbaum (2007, 2012) show how the model can solve various supply chain issues. SCOR can play a significant role in digital supply chains. For example, SCOR could be used with smart contracts enabled with blockchain technology, using metrics to determine performance levels and incentive payments. The internet of things could also benefit by leveraging metric definitions and calculations to complete edge computing activities in a standard format, providing an easier aggregation of all IoT inputs.

However, one of SCOR's best uses is as a common language for supply chain management. SCOR, the Rosetta Stone of supply chain management, is used as a translator of unique supply chain activities and measures into more universally understood processes and metrics. This capability can improve integration as supply chains become more automated and digital. These and the other examples of digital supply chains provide the answer to the research question (RQ3): "What uses stem from the development of this model?"

Recommendations for Future Research

It is recommended that the SCOR 12.0 basic formal ontology be tested in an actual supply chain environment in one of two ways. First, the organization metrics, such as Air Force metrics, could be linked to SCOR 12.0 metrics and evaluated for corresponding accuracy. A second method evaluates how well the ontology can support inter-organizational information exchanges. Ericcson, Inc., a European technology firm and their supply chain partners used SCOR 11.0 to test if standardize data could accelerate the ordering process.

SCOR 12.0 metrics are defined as classes which can be linked to an organization's supply chain processes as *individuals.* For example, these *individuals* would represent how the Air Force supply chain captures and calculates a given metric. From this information it can be determined where the Air Force metric would link or align to the cooresponding SCOR metric. For example, within the United States Air Force, perfect order fulfillment is not defined as such since the measurements are labeled differently. By mapping these to the SCOR metrics, a standard definition and calculation are agreed upon by strategic suppliers such as General Electric, Pratt & Whitney, Lockheed Martin, and Boeing. Using more commercially understood metrics improved discussions, which in turn improved performance. Figure 39 shows the mapping of Air Force metrics' contract lead time and production lead time (PLT). The ability to link Air Force data, such as current inventory, to the SCOR source planning processes of *identify*, *assess*, and *aggregate product resources* (sP2.2) is shown in Figure 40.

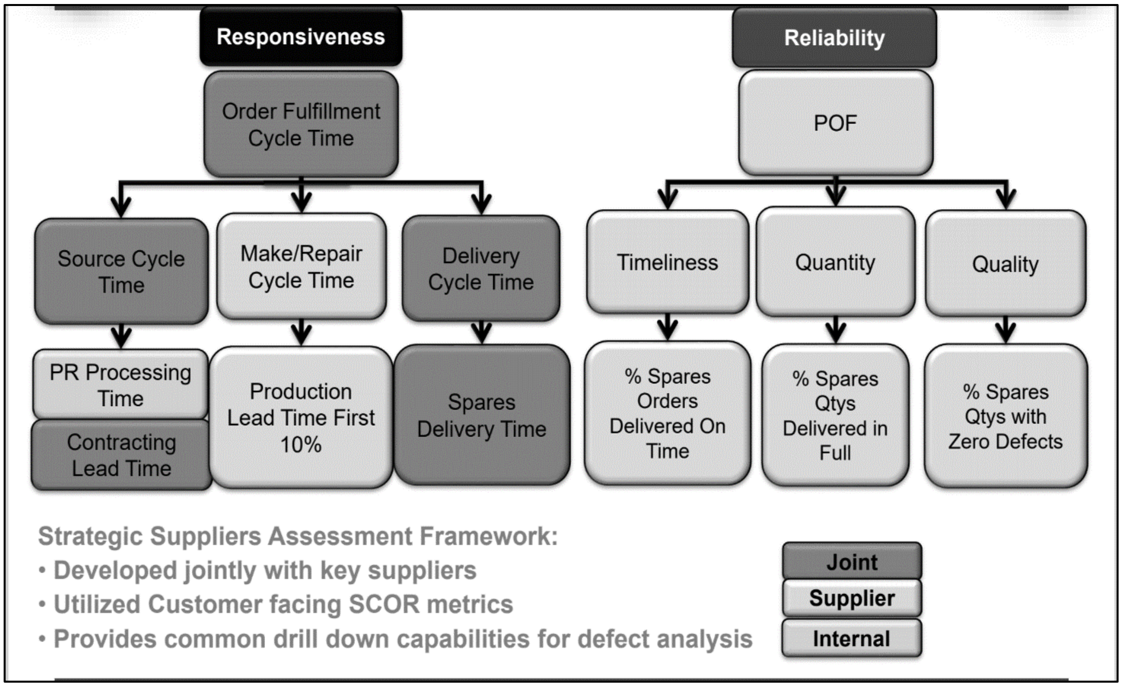

Figure 39. SCOR Metrics Linked to AFSC Metric

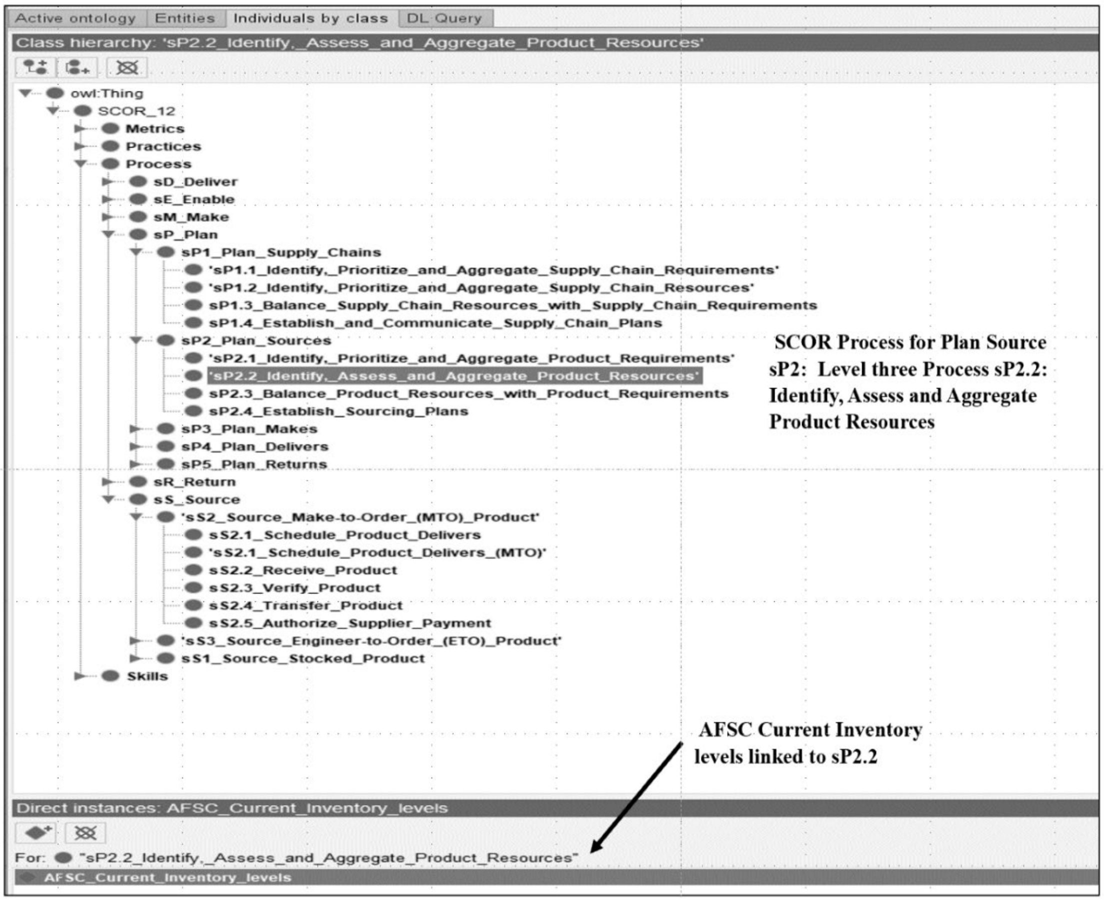

Figure 40. AFSC Current Inventory Levels Linked to SCOR sP2.2

The second test for the SCOR model, to be conducted in the natural environment, was proposed by Mr. Lars Magnusson of Ericcson Inc. Leveraging the SCOR model's integrated elements of *process*, *metrics*, *practices*, and *skills*, enables implicit business rules as found in the analogue text made explicit by the ontology approach. An example of this is how the introduction of the business rule within the metrics element enabled faster setup of performance management systems at Ericcson and their suppliers (Figure 41). The SCOR ontology's implicit business rules mapping is shown in Figure 42.

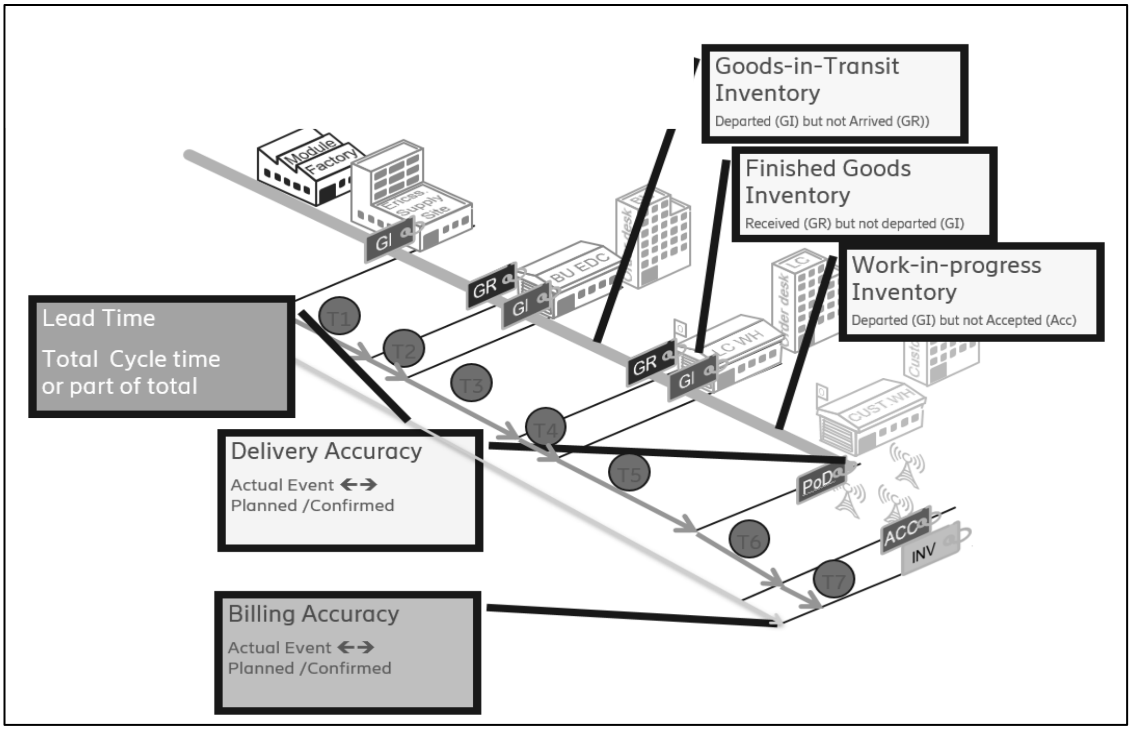

Figure 41. Example of Event Triggers Based on Performance Metrics

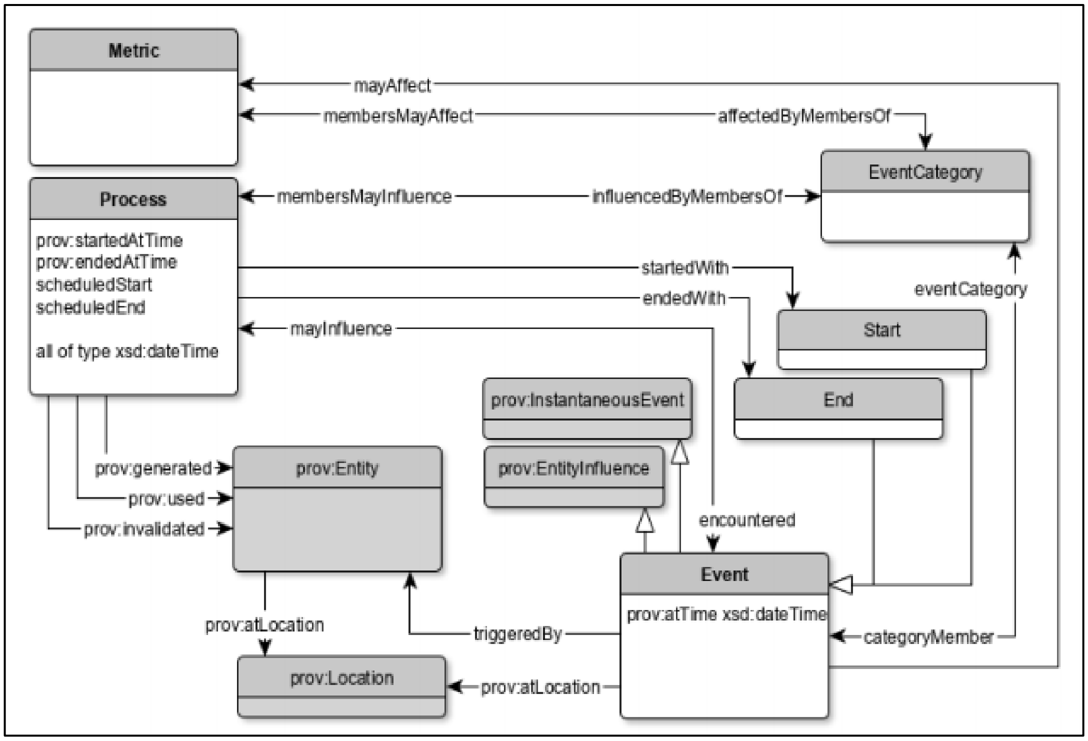

Figure 42. Example of SCOR Ontology with Implicit Business Rules

With this type of ontology background, the translation between metrics and expected performance in a real flow becomes a method, possibly supported by machine learning technology. This would in turn lead to faster implementation of standard metrics in a business flow, as shown in this example.

The next step then is to judge if the collected metrics data fulfills requirements for the specific supply chain (Figure 43). Here the ability to express specific business rules or policies in an ontology is critical, as it provides machine-readable context to the more descriptive aspects of a SCOR ontology.

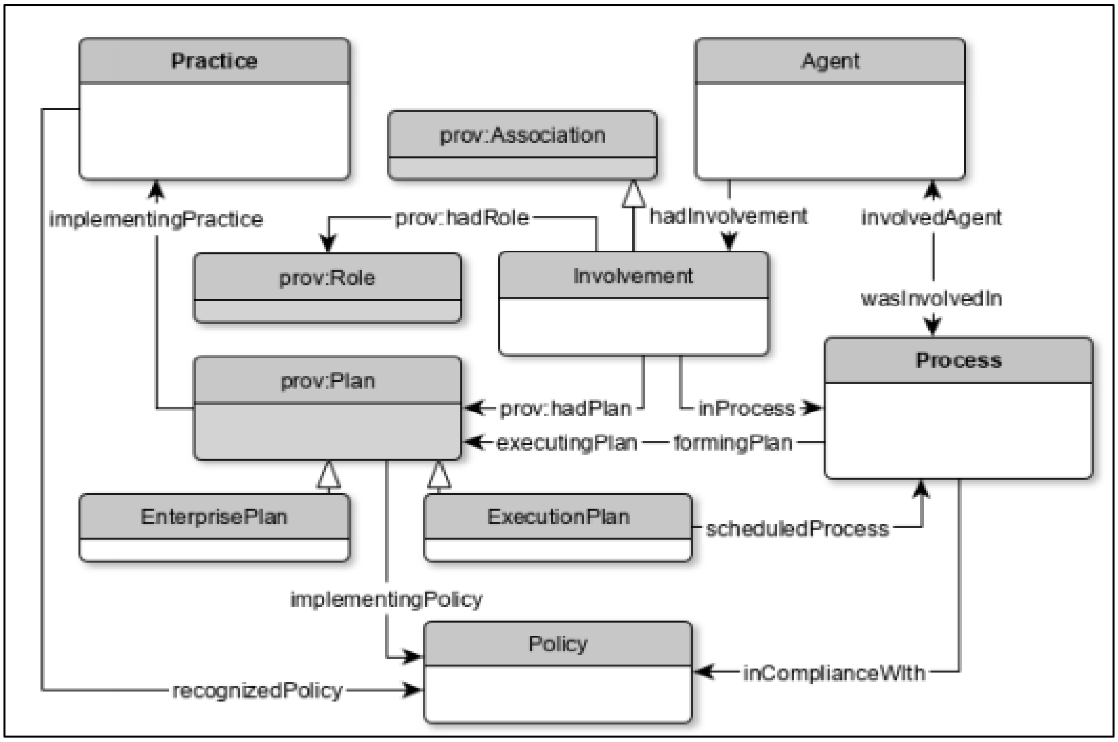

Figure 43. Example of SCOR Ontology Metrics Verified to Plan

This allows a pro-active adjustment to the process allowing it to meet the established objectives and enable the use of advanced analytics and AI based decision support. This is a multi-enterprise live validation of an ontology-based approach that provides substantial improvements.

Finally, it is recommended that new software versions and applications such as Protégé be analyzed to determine their usefulness.

SCOR 12.0 Recommended Improvements

Several enhancements are recommended for the SCOR 12.0 model. The first is to formally document where the SCOR 12.0 ontology aligns and links to other ontologies. The identification of the linkage points should include the data definition of what is being passed, the direction of the flow, and any special rule(s) or information concerning the data. This enhancement would allow ontology users to better understand the linkages with related ontologies and the data being shared between them.

Another recommendation made by members of ASCM is that SCOR 12.0 be updated to include a data model on the same level of significance as the model's processes, metrics, practices, and skills. While this would be an arduous undertaking, it would provide significant benefits to firms working to digitialize their supply chains. The enhancement would be in the form of a logical data model with formal definitions, where the data element is generated when it is used.

Finally, once the model is validated by natural test cases it should be maintained and updated by a designated set of users and approved by a governance team. This will help to maintain and improve the model's relevance and integrity.

Managerial Implications

Supply chains continue to change, especially in the area of information technology and digital transformation (Moffat, 2009), which significantly change supply chain performance and operations impacting supply chain practitioners. The amount of data available is growing everyday and the problems with organizing, storing, retrieving, and integrating this data is an ongoing problem that can only be managed with the use of computers and databases. However, this complexity can be reduced and better understood when described via a standard language and model. For example, information standardization allows information to be more interoperable, shareable, and reusable. The supply chain basic formal ontology developed by this research can greatly aid this standardization by defining supply chain terms, systematizing metric calculations, organizing processes and orchestrating the actions of organizations more consistently.

Supply chain practitioner can benefit from a supply chain basic formal ontology by having data defined and organized in a consistent manner. The source of both human and technological idiosyncrasy is that individuals use different formats and technology to capture and store data. In fact, many data scientists and researchers say that it is the diversity of the data types being used and not the quality of the data that is holding back the research (Arp et al., 2015) due to the lack of standards for the data. The SCOR 12.0 basic formal ontology can establish standards and be used to drive consistency in data discriptions and organization. Many supply chain researchers already use the SCOR processes as a way of organizing and describing the various supply chain processes. However, it must be pointed out that this ontology is only for SCOR 12.0 which is available upon request from the author.

Many supply chains have recently experienced disruptions and stockouts due to the Covid-19 pandemic. These disruptions have accelerated the need for changes to supply chain architecture and operations. While many of these planned changes in supply chain architecture and operations have been forecasted for a while, they have now become imperative for competition. The majority of these supply chain changes and improvements revolve around digitalization of the supply chain. The founder and executive chairman of the World Economic Forum states that world economies are currently in a fourth industrial revolution due to increased use of technology and digitization (Schwab, 2017). The warnings of other thought leaders are even grimmer, as some foresee a mass extinction of firms and organizations that do not adapt to the digital future (Siebert, 2019).

Research shows that efficient supply chain management needs consistent information exchanges to be established and managed (Forger, 2018). However, these exchanges are often hampered by semantic diffrences between the interfacing applications (Sakka, et. al. 2001, 2010). Many supply chain organizations have used the SCOR model to drive improvements and gain a competitive advantage (Bolstorff and Rosenbaum, 2002). Mapping supply chain processes to a standard framework like SCOR 12.0 can be accelerated and used to identify processes for technology insertion (ASCM, 2021).

Using a model driven architecture with a supporting basic formal ontology provides an abstraction layer and semantics that can save time and money for supply chain organizations. This can free programmers from much of the "data mapping, API (application program interface) syntax, and the mechanics of the myriad computational processes like ETL (extract transform and load), queuing, pipeline, [and] encryption" required in traditional development IT projects (Siebel, 1999). Model driven architecture approaches can reduce the number of entities, objects, and processes that a programmer needs to understand by an order of 10^{13} to 10^{3}, decreasing cost and complexity (Siebel, 2019).

It is envisioned that this research will provide supply chain practionioners with an ontology that they understand. In addition, the ontology can be translated into a variety of computer languagues for use by information technology professionals. This provides the information technology architects with an ontology that can used to build an information technology that alignes with supply chain proceeses and activities. In addition, it can do so faster and at a lower cost.

Closing Comments

Information is fundamental to all supply chains and technology is an important way to improve interconnectivity and integration with suppliers and customers. A basic formal supply chain ontology helps to define and organize supply chain information resulting in cost savings and improved understanding of the data. Many forecast that economies are entering a fourth industrial revolution driven by big data, the Internet of Things, cloud computing and advanced analytics; all linked to information. Organizations that fail to understand their data risk falling behind competitors that are already leveraging their supply chain information to make more informed decisions faster. While there are no easy ways to complete the move to a digital supply chain, adapting the SCOR 12.0 basic formal supply chain ontology can accelerate the transition.

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Appendix A

SCOR 12.0 XML/OWL Model


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  <NamedIndividual IRI="#sD2.13_Receive_and_Verify_Product_by_Customer"/>
</ClassAssertion>
<ClassAssertion>
  <Class IRI="#sD2_Deliver_Make-to-Order_(MTO)_Product"/>
  <NamedIndividual IRI="#sD2.14_Install_Product"/>
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  <Class IRI="#sD2_Deliver_Make-to-Order_(MTO)_Product"/>
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    <NamedIndividual IRI="#sD2.15_Invoice"/>
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    <NamedIndividual IRI="#sD2.1_Process_Inquiry_and_Quote"/>
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    IRI="#sD2.3_Reserve_Inventory_and_Determine_Delivery_Date"/>
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    <NamedIndividual IRI="#sD2.4_Consolidate_Orders"/>
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    <NamedIndividual IRI="#sD2.5_Build_Loads"/>
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    <NamedIndividual IRI="#sD2.6_Route_Shipments"/>
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    <NamedIndividual IRI="#sD2.7_Select_Carriers_and_Rate_Shipments"/>
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    <NamedIndividual IRI="#sD2.8_Receive_Product_from_Source_or_Make"/>
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    <NamedIndividual IRI="#sD2.9_Pick_Product"/>
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  <ClassAssertion>
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    <NamedIndividual IRI="#sD3.10_Pack_Product"/>
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  <NamedIndividual IRI="#sD3.14_Install_Product"/>
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  <NamedIndividual IRI="#sD3.15_Invoice"/>
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  IRI="#sD3.1_Obtain_and_Respond_to_Requests_for_Proposals"/>
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  <NamedIndividual IRI="#sD3.2_Negotiate_and_Receive_Contract"/>
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  IRI="#sD3.3_Enter_Order_Commit_Resources_and_Launch_Program"/>
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  <NamedIndividual IRI="#sD3.4_Schedule_Installation"/>
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  <Class IRI="#sD3_Deliver_Engineer-to-Order_(ETO)_Product"/>
  <NamedIndividual IRI="#sD3.5_Build_Loads"/>
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    <NamedIndividual IRI="#sD3.7_Select_Carriers_and_Rate_Shipments"/>
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  <ClassAssertion>
    <Class IRI="#sD3_Deliver_Engineer-to-Order_(ETO)_Product"/>
    <NamedIndividual IRI="#sD3.8_Receive_Product_from_Source_or_Make"/>
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  <ClassAssertion>
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    <NamedIndividual IRI="#sD4.1_Generate_Stockage_Schedule"/>
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    <NamedIndividual IRI="#sD4.2_Receive_Product_at_Store"/>
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    <NamedIndividual IRI="#sD4.3_Pick_Product_from_Backroom"/>
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    <NamedIndividual IRI="#sD4.4_Stock_Shelf"/>
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    <NamedIndividual IRI="#sD4.5_Fill_Shopping_Cart"/>
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    <NamedIndividual IRI="#sD4.6_Checkout"/>
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    <NamedIndividual IRI="#sD4.7_Deliver_and_Install"/>
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    <Class IRI="#sDR1_Deliver_Return_Defective_Product"/>
    <NamedIndividual IRI="#sDR1.1_Authorize_Defective_Product_Return"/>
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    <NamedIndividual IRI="#sDR1.2_Schedule_Defective_Return_Receipt"/>
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    <NamedIndividual IRI="#sDR1.3_Receive_Defective_Product"/>
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    <NamedIndividual IRI="#sDR1.4_Transfer_Defective_Product"/>
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    <NamedIndividual IRI="#sDR3.1_Authorize_Excess_Product_Return"/>
  </ClassAssertion>
  <ClassAssertion>
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    <NamedIndividual IRI="#sDR3.2_Schedule_Excess_Return_Receipt"/>
  </ClassAssertion>
  <ClassAssertion>
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    <NamedIndividual IRI="#sDR3.3_Receive_Excess_Product"/>
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    <Class IRI="#sDR3_Deliver_Return_Excess_Product"/>
    <NamedIndividual IRI="#sDR3.4_Transfer_Excess_Product"/>
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    <NamedIndividual IRI="#sE1.1_Gather_Business_Rule_Requirements"/>
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    <NamedIndividual IRI="#sE1.2_Interpret_Business_Rule_Requirements"/>
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    <NamedIndividual IRI="#sE1.3_Document_Business_Rules"/>
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    <NamedIndividual IRI="#sE1.4_Communicate_Business_Rules"/>
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    <NamedIndividual IRI="#sE1.5_Release_and_Publish_Business_Rules"/>
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    <NamedIndividual IRI="#sE10.1_Develop_Strategy_and_Plan"/>
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    <NamedIndividual IRI="#sE10.2_Pre-
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    <NamedIndividual IRI="#sE10.3_Develop_Procurement_Documentation"/>
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    <NamedIndividual IRI="#sE10.6_Bid_or_Tender_Evaluation_and_Validation"/>
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    <NamedIndividual IRI="#sE10.7_Contract_Award_and_Implementation"/>
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    <NamedIndividual
    IRI="#sE11.1_Define_Supply_Chain_Technology_Requirements"/>
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    <NamedIndividual IRI="#sE11.2_Identify_Technology_Solution_Alternatives"/>
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    <NamedIndividual IRI="#sE11.5_Deploy_Technology_Solution"/>
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    IRI="#sE11.6_Maintain_and_Improve_Technology_Solution"/>
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    <NamedIndividual IRI="#sE11.7_Retire_Technology_Solution"/>
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    <NamedIndividual IRI="#sE2.2_Analyze_Reports"/>
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    <NamedIndividual IRI="#sE2.4_Prioritize_Root_Causes"/>
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    <NamedIndividual IRI="#sE2.5_Develop_Corrective_Actions"/>
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  <NamedIndividual IRI="#sE3.4_Maintain_Access"/>
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  <Class IRI="#sE3_Manage_Data_and_Information"/>
  <NamedIndividual IRI="#sE3.5_Publish_Information"/>
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  <Class IRI="#sE3_Manage_Data_and_Information"/>
  <NamedIndividual IRI="#sE3.6_Verify_Information"/>
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  <NamedIndividual IRI="#sE4.1_Identify_Skill_and_Resource_Requirements"/>
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  <NamedIndividual IRI="#sE4.2_Identify_Available_Skills_and_Resources"/>
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  <NamedIndividual IRI="#sE4.6_Approve_Prioritize_and_Launch"/>
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  <NamedIndividual IRI="#sE5.1_Schedule_Asset_Management_Activities"/>
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  <NamedIndividual IRI="#sE5.3_Inspect_and_Troubleshoot"/>
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  <NamedIndividual IRI="#sE5.4_Install_and_Configure"/>
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    <NamedIndividual IRI="#sE6.7_Select_Prioritize_and_Distribute_Resolutions"/>
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  <Class IRI="#sM1_Make-to-Stock_(MTS)"/>
  <NamedIndividual IRI="#sM1.3_Produce_and_Test"/>
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  <NamedIndividual IRI="#sM1.4_Package_Product"/>
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  <Class IRI="#sM2_Make-to-Order_(MTO)"/>
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  <NamedIndividual IRI="#sS2.5_Authorize_Supplier_Payment"/>
</ClassAssertion>
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  <NamedIndividual IRI="#sS3.5_Verify_Product"/>
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  <NamedIndividual IRI="#sSR1.1Identify_Defective_Product_Condition"/>
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  <Class IRI="#sSR1_Source_Return_Defective_Product"/>
  <NamedIndividual IRI="#sSR1.2_Disposition_of_Defective_Product"/>
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  <Class IRI="#sSR1_Source_Return_Defective_Product"/>
  <NamedIndividual IRI="#sSR1.4_Schedule_Defective_Product_Shipment"/>
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  <Class IRI="#sSR1_Source_Return_Defective_Product"/>
  <NamedIndividual IRI="#sSR1.5_Return_Defective_Product"/>
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  <Class IRI="#sSR3_Source_Return_Excess_Product"/>
  <NamedIndividual IRI="#sSR3.1_Identify_Excess_Product_Condition"/>
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  <NamedIndividual IRI="#sSR3.2_Disposition_of_Excess_Product"/>
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  <NamedIndividual
  IRI="#sSR3.3_Request_Excess_Product_Return_Authorization"/>
</ClassAssertion>
<ClassAssertion>
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  <NamedIndividual IRI="#sSR3.4_Schedule_Excess_Product_Shipment"/>
</ClassAssertion>
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  <Class IRI="#sSR3_Source_Return_Excess_Product"/>
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    <ObjectProperty IRI="#hasSkills"/>
  </FunctionalObjectProperty>
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    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#SR.1.1_Order_Fulfillment_Cycle_Time</IRI>
    <Literal>The average actual cycle time consistently achieved to fulfill customer
    orders. For each individual order, this cycle time starts at the order receipt and
    ends at customer acceptance of the order.
Calculation
(Sum actual cycle times for all orders delivered / Total number of orders delivered)
This metric is measured in days.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD2.11_Load_Product_and_Generate_Shipping_Documents</IRI>
    <Literal>The process of loading products onto modes of transportation and
    generating the invoice and other documentation required to meet internal,
    customer, carrier and government needs. This process may also include
    verifying the customer’s credit, if that has not already been done.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD2.12_Ship_Product</IRI>
    <Literal>The process of shipping the product to the customer site</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD2.13_Receive_and_Verify_Product_by_Customer</IRI>
    <Literal>The process of the customer receiving the product at the customer site
    or at the shipping area, in the case of self-collection, and verifying that the order
    is complete and that the product meets the delivery terms.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD2.14_Install_Product</IRI>
    <Literal>The process of preparing, testing and installing the product at the
    customer site, if necessary. The product is fully functional upon
    completion.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
```

```
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD2.15_Invoice</IRI>
    <Literal>The process of sending a signal to the financial organization to indicate
    that the order has been shipped and that the billing process should begin. The
    order can be closed if payment was received in advance. Otherwise, payment
    should be received from the customer within the payment terms of the
    invoice.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD2.1_Process_Inquiry_and_Quote</IRI>
    <Literal>The process of receiving and responding to general customer inquiries
    and requests for quotes.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD2.2_Receive_Configure_Enter_and_Validate_Order</IRI>
    <Literal>The process of receiving orders from customers and entering them
    into the company&apos;s order-processing system. Configure the product to the
    customer&apos;s specific needs and based on standard available parts or
    options. Technically examine the order to ensure an orderable configuration
    and provide an accurate price. Also, check the customer&apos;s credit as
    required by business rules. In some cases, payment may be accepted
    now.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD2.3_Reserve_Inventory_and_Determine_Delivery_Date</IRI>
    <Literal>The process of identifying on-hand and scheduled inventory and
    reserving it for specific orders. It also includes scheduling a delivery
    date.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD2.4_Consolidate_Orders</IRI>
    <Literal>The process of analyzing orders to determine the groupings that result
    in the lowest cost or the best service fulfillment and transportation.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD2.5_Build_Loads</IRI>
    <Literal>The process of selecting transportation modes and building efficient
    loads.</Literal>
  </AnnotationAssertion>
```

```
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sD2.6_Route_Shipments</IRI>
  <Literal>The practice of consolidating loads and routing them by mode, lane
  and location.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sD2.7_Select_Carriers_and_Rate_Shipments</IRI>
  <Literal>The process of selecting carriers and rating and tendering shipments.
  Organizations typically select carriers based on a variety of criteria that can
  include the cost per route, speed, schedule and performance.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sD2.8_Receive_Product_from_Source_or_Make</IRI>
  <Literal>The activities of receiving a product, verifying it, recording its receipt,
  determining the put-away location, putting it away and recording the location.
  This process may also include quality inspection.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sD2.9_Pick_Product</IRI>
  <Literal>The series of activities including retrieving orders to pick, verifying
  inventory availability, building the pick wave, picking the product, recording the
  pick and delivering the product to the packing area in response to an
  order.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sD3.10_Pack_Product</IRI>
  <Literal>The activities of sorting and combining products, packing or kitting
  them, applying labels and bar codes, and delivering the products to the shipping
  area for loading.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sD3.11_Load_Product_and_Generate_Shipping_Documents</IRI>
  <Literal>The process of loading products onto modes of transportation and
  generating the invoice and other documentation required to meet internal,
  customer, carrier and government needs. This process may also include
  verifying the customer's credit, if that has not already been done.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
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    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD3.12_Ship_Product</IRI>
    <Literal>The process of shipping the product to the customer site.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD3.13_Receive_and_Verify_Product_by_Customer</IRI>
    <Literal>The process of the customer receiving the product at the customer site
    or at the shipping area, in the case of self-collection, and verifying that the order
    is complete and that the product meets the delivery terms</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD3.14_Install_Product</IRI>
    <Literal>The process of preparing, testing and installing the product at the
    customer site, if necessary. The product is fully functional upon
    completion.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD3.15_Invoice</IRI>
    <Literal>The process of sending a signal to the financial organization to indicate
    that the order has been shipped and that the billing process should begin. The
    order can be closed if payment was received in advance. Otherwise, payment
    should be received from the customer within the payment terms of the
    invoice.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD3.1_Obtain_and_Respond_to_Requests_for_Proposals</IRI>
    <Literal>The process of receiving an RFP or RFQ; evaluating the request by
    estimating the schedule, developing costs estimates and establishing a price;
    and responding to the potential customer.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD3.2_Negotiate_and_Receive_Contract</IRI>
    <Literal>The process of negotiating order details, including price, schedule and
    product performance, with a customer and finalizing the contract. This process
    may also include accepting payment</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD3.3_Enter_Order_Commit_Resources_and_Launch_Program</IRI>
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    <Literal>The process of entering and finalizing the customer’s order; approving
    the planned resources, including engineering and manufacturing resources; and
    officially launching the program.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD3.4_Schedule_Installation</IRI>
    <Literal>The process of evaluating the design and building schedules relative to
    the customer-requested installation date to determine the installation
    schedule.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD3.5_Build_Loads</IRI>
    <Literal>The process of selecting transportation modes and building efficient
    loads.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD3.6_Route_Shipments</IRI>
    <Literal>The process of consolidating loads and routing them by mode, lane and
    location.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD3.7_Select_Carriers_and_Rate_Shipments</IRI>
    <Literal>The process of selecting carriers and rating and tendering shipments.
    Organizations typically select carriers based on a variety of criteria that can
    include the cost per route, speed, schedule and performance. In many cases,
    organizations also need to seek out specialized carriers that are equipped to
    handle their engineer-to-order products.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD3.8_Receive_Product_from_Source_or_Make</IRI>
    <Literal>The activities of receiving a product, verifying it, recording its receipt,
    determining the put-away location, putting it away and recording the location.
    This process may also include quality inspection.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD3.9_Pick_Product</IRI>
    <Literal>The series of activities including retrieving orders to pick, verifying
    inventory availability, building the pick wave, picking the product, recording the
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    pick and delivering product to the packing area in response to an
    order.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD4.1_Generate_Stockage_Schedule</IRI>
    <Literal>The process of scheduling resources to support item-stocking
    requirements.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD4.2_Receive_Product_at_Store</IRI>
    <Literal>The activities of receiving products at a retail store, verifying them,
    recording their receipt, determining put-away locations, putting the items away
    and recording their locations. This process may also include quality
    inspection.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD4.3_Pick_Product_from_Backroom</IRI>
    <Literal>The process of receiving picking orders for restocking, determining
    inventory availability, building a pick wave, picking items from backroom
    storage, recording the resulting inventory transactions and delivering the
    products to the point of stock.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD4.4_Stock_Shelf</IRI>
    <Literal>For restocks, the tasks associated with identifying item locations,
    stocking the shelf according to merchandise plans and recording the
    appropriate inventory transactions. For promotional items and stock
    repositioning, the tasks associated with shelf and point-of-sale preparation,
    stock placement, and end-of-sale activities.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD4.5_Fill_Shopping_Cart</IRI>
    <Literal>The typical set of tasks associated with product selection, storage and
    movement through to checkout.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD4.6_Checkout</IRI>
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    <Literal>The processes and tasks associated with product checkout, including
    scanning, payment, credit application and approval, service agreements, order
    confirmation, and invoice or receipt.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sD4.7_Deliver_and_Install</IRI>
    <Literal>The process of preparing and installing the product at the customer
    site. The product is fully functional upon completion.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sDR1.1_Authorize_Defective_Product_Return</IRI>
    <Literal>The process in which the last known holder or the designated return
    center receives a defective product return authorization request from a
    customer, determines if the item can be accepted and communicates the
    decision to the customer. Accepting the request includes negotiating the
    conditions of the return with the customer, including authorizing replacement
    or credit. Rejecting the request includes providing a reason for the rejection to
    the customer. This process also can apply to planning for items that are being
    returned for upgrade.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sDR1.2_Schedule_Defective_Return_Receipt</IRI>
    <Literal>The process in which the last known holder or the designated return
    center evaluates the defective product handling requirements, including
    negotiated conditions, and develops a schedule that tells the customer when to
    ship the product. The scheduling activity would also inform the receiving
    department about when to expect the shipment and where to send the product
    upon receipt for disposition. This process also can apply to items that are being
    returned for upgrade.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sDR1.3_Receive_Defective_Product</IRI>
    <Literal>The process in which the last known holder or the designated return
    center receives and verifies the returned defective product or product being
    returned for upgrade against the return authorization and other documentation
    and prepares the item for transfer.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sDR1.4_Transfer_Defective_Product</IRI>
```

<Literal>The process in which the last known holder or the designated return center transfers the defective product or the product being returned for upgrade to the appropriate process to implement the disposition decision or upgrade work.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sDR3.1_Authorize_Excess_Product_Return</IRI>
<Literal>The process in which the designated return center receives an excess product return authorization request from a customer, determines if the item can be accepted and communicates the decision to the customer. Accepting the request includes negotiating the conditions of the return with the customer, including authorizing a credit or cash discount. Rejecting the request includes providing a reason for the rejection to the customer. This process also can be applied to products that are unwanted because of size, style, color or other customer preferences.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sDR3.2_Schedule_Excess_Return_Receipt</IRI>
<Literal>The process in which the designated return center evaluates an authorized excess material return to determine packaging and handling requirements. This assessment will lead to the development of a return disposition decision and a return schedule with terms and conditions that will tell the customer how and when to ship the product. The scheduling activity would also inform the receiving department about when to expect the shipment and where to send the product upon receipt for disposition. This process also can be applied to products that are unwanted because of size, style, color or other customer preferences.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sDR3.3_Receive_Excess_Product</IRI>
<Literal>The process in which the designated return center receives and verifies the returned excess product and associated documentation against the return authorization and other documentation and prepares the item for transfer. This process also can be applied to products that are unwanted because of size, style, color or other customer preferences.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sDR3.4_Transfer_Excess_Product</IRI>
<Literal>The process in which the designated return center transfers the excess product to the appropriate process to implement the disposition decision. This

process also can be applied to products that are unwanted because of size, style, color or other customer preferences.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE1.1_Gather_Business_Rule_Requirements</IRI>
<Literal>The process of collecting, organizing, prioritizing and scheduling policies and directives requiring new supply chain business rules, changes to business rules or discontinuation of business rules. This may include scheduling and assigning activities to responsible individuals, groups or organizations.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE1.2_Interpret_Business_Rule_Requirements</IRI>
<Literal>The process of determining how the policy or directive impacts supply chain processes, technology and business rules. This includes reviewing existing business rules and determining the need to add, change or delete business rules. The outcome is one or more of the following:

•Someone submits a request to add a business rule.
•Someone submits a request to change a business rule.
•Someone submits a request to delete or archive a business rule.

The purpose of this step is to identify the type of activities required and then route the request(s), if required.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE1.3_Document_Business_Rules</IRI>
<Literal>The process of writing the business rule in the appropriate system of record. This includes adding, editing and deleting policy and process documentation. A business rule should include a directive or policy, scope and effective date. Updates to existing business rules may include discontinuation information.
The final activity of Document Business Rule is obtaining formal approval. The output of this process step is a fully documented business rule that is approved by the responsible function.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE1.4_Communicate_Business_Rules</IRI>
<Literal>The process of creating awareness in the relevant organization and among the relevant staff of the upcoming changes. This may include

communication, training and education programs. For small or incremental changes, a notice maybe sufficient.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE1.5_Release_and_Publish_Business_Rules</IRI>
<Literal>The process of activating the business rule. This may include activation of a business rule in a software algorithm and starting to use a new or updated standard operating procedure. For large-impact business rule changes, this process may include updating external websites and formal notifications to supply chain partners. For business rules enacted in software and automated systems, this process should include appropriate modeling and testing prior to full activation in production instances.
The release of a business rule may be time-phased, such as a bill of materials release for newer revisions.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE1.6_Retire_Business_Rule</IRI>
<Literal>The process of deactivating a business rule. This may include archiving the business rule in the associated software to prevent users from inadvertently using it or in order to comply with regulatory requirements or policies.
The retirement of a business rule may be time-phased, such as a bill of materials being replaced by newer revisions.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE10.1_Develop_Strategy_and_Plan</IRI>
<Literal>The process of developing a sourcing strategy or plan to procure the products and services required by the organization. Inputs into this process include specifications, business requirements and marketplace assessments. The sourcing strategy or plan must adhere to external laws and regulations as well as internal policies and guidelines. Supply chain risks also must be accounted for in this plan.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE10.2_Pre-
Procurement_and_Market_Test_and_Market_Engagement</IRI>
<Literal>The activities associated with testing the market to determine if it is the right time to release a product or service into the marketplace. This process might uncover other factors to consider, including crop cycles, what competitors are doing, supplier performance and new legislation.

Market development identifies stakeholder and business needs as well as the changes required in order to implement the procurement strategy to meet those needs flexibly.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE10.3_Develop_Procurement_Documentation</IRI>
<Literal>The process of developing the tender documents, including a detailed breakdown of the volumes, service-level agreement, and terms and conditions, along with a detailed specification to ensure consistency on pricing, product quality and the operational functionality of products. Ensuring correct product purpose can reduce the financial impact of incorrect specifications further upstream.

Care must be taken to understand the distinction between product requirements and product preferences, to build in tolerances for suppliers to adhere to, and to not restrict the supply or build cost into the product. The specification will form part of the tender documentation issued to suppliers to quote on a like-for-like basis.

Note: A tender is a written offer to contract goods or services at a specified cost or rate.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE10.6_Bid_or_Tender_Evaluation_and_Validation</IRI>
<Literal>The process of evaluating and validating bids and proposals in order to select the preferred supplier(s). Tender evaluation should be carried out in a structured, disciplined and transparent manner, regardless of whether the contracts are for the supply of goods or the supply of services. Most evaluations explore price comparisons alongside technical capabilities, capacity, quality of service and the financial health of the supplier.

At this stage, a post-tender negotiation often takes place, along with reference and credit checks, a supplier visit, a technical audit, product sampling or a trial. Whole-life costs should also be considered, including decommissioning, removal or disposal costs.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE10.7_Contract_Award_and_Implementation</IRI>
<Literal>The process of developing a contract that allows both the customer and the chosen supplier to fully understand the obligations and key success criteria of the agreement. The agreed terms and conditions help to minimize contractual risks and exposure when doing business. Once the contract and terms are agreed upon, then the communication and implementation process can begin. Clear timelines and parameters should be set up on both sides. Both

parties also should form relevant stakeholder groups to manage the contract implementation effectively.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE11.1_Define_Supply_Chain_Technology_Requirements</IRI>
<Literal>The activities associated with defining specific business process and information technology requirements for the business processes in scope. A comprehensive evaluation of requirements involves internal and external research to develop robust requirements that consider strategic performance characteristics and goals, regulatory and compliance requirements, and leading and emerging practices from within the industry and across industries. Take care not to codify legacy processes and practices as requirements unless they are compulsory, provide a strategically differentiating capability or are reflective of leading practices based on external research.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE11.2_Identify_Technology_Solution_Alternatives</IRI>
<Literal>The activities associated with surveying and evaluating available technology options and capabilities. These activities can and should occur in parallel with Define Supply Chain Technology Requirements (sE11.1) so that unvetted requirements do not prematurely shape and direct technology or solution research and evaluation. Companies should make it a business practice to regularly monitoring available technology options to better understand what opportunities are possible and the risk profiles of various technology alternatives.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>

<IRI>#sE11.3_Define_and_Update_Supply_Chain_Information_Technology_Roadmap</IRI>
<Literal>The activities associated with synthesizing supply chain capability requirements and technology alternatives into an overarching plan for new technology adoption and implementation. Transitioning from existing to new technologies is typically a highly complex endeavor that becomes more and more complex as levels of integration continue to increase. With the high degree of interaction among integrated technology systems and data flows, effective adoption and integration of new technologies requires a carefully constructed, time-phased plan or roadmap. All businesses should maintain a technology roadmap across the enterprise, with specific, detailed roadmaps for core business process domains, such as supply chain. An effective roadmap shows the time-phased path from the existing technologies to new technologies,

including any transitional and phased or bridged solutions. Roadmaps should reflect a 3-5-year horizon but are always subject to change based on acceleration of emerging technologies, competitor behaviors, customer requirements or disruptive changes in the value chain. Adding a technology solution to the roadmap is not as detailed and specific of an exercise as technology selection activities in Select Technology Solution (sE11.4). Roadmaps are intended to be guidance and are subject to detailed evaluation and selection.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE11.4_Select_Technology_Solution</IRI>
<Literal>The activities associated with the detailed matching of business requirements to the capabilities of technology alternatives to determine the best overall solution, considering fit to requirements, compatibility with other integrating technologies, risks and total costs of ownership for the technology. Technology selection is a cross-functional activity and is most effective when comprehensive selection criteria and weightings are defined in advance.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE11.5_Deploy_Technology_Solution</IRI>
<Literal>The activities associated with developing, configuring, testing, piloting and fully deploying new supply chain technologies. The specific technical activities involved in technology deployment are represented in information technology implementation best practice approaches and models. Supply chain–related activities involve assessing and mitigating the supply chain risks associated with implementation issues and delays, possibly including

•incorrect information being passed to customers, suppliers or supply chain partners
•supply chain delays and missed delivery dates
•incorrect inventories
•erroneous plans
•product quality issues.

Supply chain management plays a vital role in understanding and preparing for technology implementation problems. Technology deployment considerations, such as downtime and lost capacity, and risk mitigations, including inventory buildup, as defined in Manage Supply Chain Risk (sE9) become important inputs into supply chain plans.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>

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    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sE11.6_Maintain_and_Improve_Technology_Solution</IRI>
    <Literal>The activities associated with continuous improvement of technology
    solution performance through ongoing performance analysis and enhancement
    of models, algorithms, data quality and inputs, and configurations. As
    technology solutions become increasingly sophisticated, it is unlikely that initial
    models and configurations used at deployment are optimal. To accelerate
    improvement cycles, consider implementing leading practices, such as the use
    of simulation and digital twins of supply chains or supply chain segments to
    rapidly evaluate and refine models and algorithms offline before implementing
    them live in the supply chain.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sE11.7_Retire_Technology_Solution</IRI>
    <Literal>The activities associated with removing a supply chain technology
    solution from active use. As with deployment, there are many technology-
    related activities associated with solution retirement that are best represented
    in information technology (IT) management models. Supply chain
    management’s focus in solution retirement should be on identifying and
    mitigating supply chain risks and ensuring that necessary data and metadata
    from the retired system are effectively preserved. Many types of supply chain
    analytics can require significant amounts of historical data beyond corporate
    archiving policies, and supply chain managers should clearly identify such data
    records and work with IT managers to ensure its continued availability and
    use.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sE2.1_Initiate_Reporting</IRI>
    <Literal>The process of scheduling and running reports and collecting and
    aggregating performance data. This includes running standard or predefined
    reports as well as ad hoc reporting. Ad hoc reporting includes developing a data
    collection plan and organizing data collection through inspections,
    measurements, sampling and self-assessments.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sE2.2_Analyze_Reports</IRI>
    <Literal>The process of reviewing the reported performance. This includes
    comparing actual performance and trends with the targets set for each metric,
    identifying metrics that require root cause analysis, notifying process owners,
    and scheduling the root cause analysis and related resources.</Literal>
  </AnnotationAssertion>
```

<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE2.3_Find_Root_Causes</IRI>
<Literal>The process of analyzing the gaps in performance. Example methods for finding root causes include

•the addition of commentary to reported data
•metrics decomposition using diagnostic relationships of SCOR metrics
•time studies, sampling, audits and cycle counting
•5 Whys and other cause-and-effect analyses
•statistical analysis techniques, such as histograms, scatter plots and analysis of variance.

All root causes are documented and quantified. Quantification is the calculation or estimation of the relative contribution to the gap in performance.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE2.4_Prioritize_Root_Causes</IRI>
<Literal>The process of sorting root causes by relative contribution to prioritize them. This includes assigning root causes to resources and scheduling the development of corrective actions.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE2.5_Develop_Corrective_Actions</IRI>
<Literal>The process of identifying, documenting and testing corrective actions to address a root cause in order to close the related performance gap. Corrections actions include

•organizational changes, such as hiring or redeployment
•policy changes
•process improvements through work instructions and training
•production equipment repairs and calibration
•supply chain network reconfiguration
•software algorithm changes, such as updates to the planning or scheduling logic
•introduction of new technology, such as new equipment, tools or software.

Note: This list of corrective actions is a general characterization for example purposes only. Different root causes may require different corrective actions.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>

<IRI>#sE2.6_Approve_and_Launch</IRI>
<Literal>The process of obtaining approvals and communicating and launching the corrective actions.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE3.1_Receive_Maintenance_Request</IRI>
<Literal>The process of receiving, validating and logging the request for information, configuration or system functionality maintenance. Maintenance request types include

•Request to Add Data, which requests the creation of a new record or document or the duplication of an existing record or document
•Request to Change Data, which requests the modification of an existing record or document
•Request to Delete Data, which requests the deletion of an existing record or the archival and unpublishing of an existing record or document
•Request to Change Configuration, which includes creating and maintaining user access
•Request to Add Code, which includes installing software and security updates
•Request to Change Code, which requests the modification of software code
•Request to Delete Code, which requests the deletion of software code.

This process may include assigning a ticket, tracking number or order number and routing the request to the appropriate resource.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE3.2_Determine_and_Scope_Work</IRI>
<Literal>The activities associated with determining the activities required to perform the requested maintenance. The requestor may be contacted for additional information. Complex requests may be set up as projects with the appropriate work breakdown structure, milestones, acceptance criteria and deliverables schedules. This process may include routing the request to the appropriate resource.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE3.3_Maintain_Content_and_Code</IRI>
<Literal>The process of formatting, entering, loading, editing or deleting the information, software updates and code changes requested. This includes verification of changes as needed through unit and integration testing. Typical changes include

•data record maintenance
•configuration changes, such as activating and disabling system functionality
•loading and installing software updates
•loading and installing security updates.

This process is not a placeholder for complex software engineering processes. Such processes fall outside of the SCOR process framework.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE3.4_Maintain_Access</IRI>
<Literal>The process of establishing, changing or removing access rights for users.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE3.5_Publish_Information</IRI>
<Literal>The process of activating the changes to information, configuration or code and populating the information to dependent systems, when applicable. For data record maintenance, this is the activation of the new data and populating of dependent systems with the new data. For example, through this process a specialist could activate a bill of materials (BOM) in the system of record and then populate dependent systems that require a copy of this data with the BOM. This process may be manual, automated or a combination of the two.

Note: A system of record is an information storage system that is the authoritative data source for a given data element or piece of information.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE3.6_Verify_Information</IRI>
<Literal>The process of verifying that information is properly recorded in the system of record and properly populated to dependent systems. This includes verifying that information is accessible to users.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE4.1_Identify_Skill_and_Resource_Requirements</IRI>
<Literal>The activities associated with the collection of the required skills to operate part of the supply chain. Examples of this process are planning meetings, periodic performance reviews and reorganizations. The data collected should list the required skills or resources and is generally organized

by entity, such as supply chain node, department, function or a combination of these.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE4.2_Identify_Available_Skills_and_Resources</IRI>
<Literal>The activities associated with collecting and identifying the skills and resources currently available in the supply chain. Generally, this information is collected and organized by entity, such as supply chain node, department, function or a combination of these. Examples of this process include data collection for standard headcount reports. Headcounts should include temporary staff and outsourced resources.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE4.3_Match_Skills_and_Resources</IRI>
<Literal>The activities associated with matching skill or resource demands with the available skills or resources. The purpose of this process is to determine which skill or resource requirements (the demand) can be met using existing resources, determine which skill or resource requirements are not supported by currently available skills or resources (the gap), and determine the skills or resources for which no demand exists (excess).
For each skill or resource gap or excess, one or more actions needs to be taken to close the gap or address the excess. Possible solutions include

•training or cross-training to add skills to existing resources
•hiring permanent, temporary or outsourced staff
•redeploying staff within the organization or laying off staff.
I
t is important to consider the lead time of these actions. Scarce skills may have longer lead times, for example.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE4.4_Determine_Hiring_and_Redeployment</IRI>
<Literal>The activities associated with identifying sources of new hires or sources and destinations for redeployment. The purposes of this process include assessing the feasibility of hiring the required skills and resources within the required time period, assessing the feasibility of redeploying the excess employees, and assessing the feasibility and impact of possible staff layoffs.
Note: At this stage this is a planning activity. The actual hiring process is not documented in SCOR, as this is a human resources process. Also, employee in

this context includes temporary workers and employees of service
providers.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE4.5_Determine_Training_and_Education</IRI>
<Literal>The activities associated with identifying training and education
programs to ensure existing and newly hired employees will have the
appropriate skills to perform the work allocated to each individual employee.
Employee in this definition includes temporary workers and employees of
service providers.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE4.6_Approve_Prioritize_and_Launch</IRI>
<Literal>The activities associated with obtaining approvals for hiring,
redeployment, training and education plans; prioritizing these plans; and
executing them. Additional resources and skills will become available over time,
adjusting the labor component of capacity in Plan, Source, Make, Deliver, Return
and Enable processes.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE5.1_Schedule_Asset_Management_Activities</IRI>
<Literal>The activities associated with receiving maintenance requests;
receiving repair, replacement or installation requests; maintaining preventive
or regular maintenance tasks; scheduling individual maintenance tasks; and
assigning resources to individual maintenance tasks. Scheduling may include
incorporating production and delivery plans and schedules and communication
of maintenance schedules to production and delivery planning and scheduling
processes.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE5.2_Take_Asset_Off-Line</IRI>
<Literal>The activities associated with preparation for maintenance tasks. In
general terms, this means the asset or piece of equipment needs to be stopped
or put into maintenance mode. Safety precautions need to be made to ensure
the equipment cannot be restarted during maintenance without active approval
of the maintenance operators or engineers. This may include installing safety
barriers, transporting the asset or piece of equipment to a location where the
maintenance will take place, removing deposits or materials from production
equipment through cleaning, and backing up data from the equipment and
associated automation systems.</Literal>

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    </AnnotationAssertion>
    <AnnotationAssertion>
        <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
        <IRI>#sE5.3_Inspect_and_Troubleshoot</IRI>
        <Literal>The activities associated with assessing the overall status of a piece of
        equipment and performing standard inspection and detailed troubleshooting, if
        required. This process includes identifying the repairs, upgrades and
        maintenance needed to bring the asset or piece of equipment back into optimal
        or acceptable working condition. It also may include identifying whether a piece
        of equipment is ready for the installation of new hardware or software and
        preparing and documenting the steps of decommissioning and disposing of
        equipment or assets.</Literal>
    </AnnotationAssertion>
    <AnnotationAssertion>
        <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
        <IRI>#sE5.4_Install_and_Configure</IRI>
        <Literal>The activities associated with the installation and testing of new
        hardware, software or functionality on equipment or assets. The general
        purpose of installation is to increase capacity or add or improve capabilities.
Note: This process may trigger the installation of new supply chain assets,
        depending on the size of the installation.</Literal>
    </AnnotationAssertion>
    <AnnotationAssertion>
        <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
        <IRI>#sE5.5_Clean_Inspect_and_Repair</IRI>
        <Literal>The activities associated with the cleaning and reconditioning of
        equipment or assets, including the replacement of parts. The general purpose of
        this process is to bring the equipment or assets back into optimal or acceptable
        operating condition. This process may include measuring and testing the
        equipment.
Note: Performing the actual maintenance and repair activities falls under the Make
        processes.</Literal>
    </AnnotationAssertion>
    <AnnotationAssertion>
        <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
        <IRI>#sE5.6_Decommission_and_Dispose</IRI>
        <Literal>The activities associated with de-installing or uninstalling and
        disposing of existing hardware, software, or functionality on equipment or
        assets. This includes physical removal from the original point of use. The
        general purpose of de-installation is to replace capacity or remove outdated
        capabilities.</Literal>
    </AnnotationAssertion>
    <AnnotationAssertion>
        <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
```

```
  <IRI>#sE6.1_Receive_Contract_or_Agreement_Updates</IRI>
  <Literal>The activities associated with receiving new contracts or changes to
  existing contracts. These contract updates may originate in the sales and
  support department, if they are for customer contracts, or in product and
  process design department, if they are for contracts with material or service
  providers. This process includes validation of contracts against criteria and
  business rules. A contract needs to include information such as effective date
  and duration, customer or supplier address, and payment terms and should not
  be in conflict with business rules or regulatory requirements.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sE6.2_Enter_and_Distribute_Contract_or_Agreement</IRI>
  <Literal>The activities associated with entering contractual information into
  document management systems and enterprise resources planning systems.
  This includes the translation of contractual language and information into a
  format that the systems can comprehend. A final step in this process is to
  distribute the contract or updates to an existing contract to the appropriate
  processes and functions.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sE6.3_Activate_or_Archive_Contract_or_Agreement</IRI>
  <Literal>The activities associated with activating or deactivating and archiving
  a contract. This may include updating statuses of information in document
  management systems or enterprise resources planning (ERP) systems. This
  activity may be triggered and performed by the document management system
  or the ERP system based on parameters entered as part of Enter and Distribute
  Contract or Agreement (sE6.2).</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sE6.4_Review_Contractual_Performance_Agreement</IRI>
  <Literal>The activities associated with reviewing the performance of
  contractual parties, including both suppliers and customers. This process
  includes comparing the contractual service-level agreements with the actual
  service levels. It may be triggered by a calendar event, such as annual or
  quarterly quality reviews, or actual performance issues identified in daily
  supply chain processes.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sE6.5_Identify_Performance_Issues_and_Opportunities</IRI>
```

<Literal>The activities associated with identifying and prioritizing key performance issues or areas of ongoing process improvement. This process includes notifying contractual partners of non-conformance to contractual agreements or service-level agreements. It also addresses both the non-compliance or severe issues as well as areas of continuous improvement, which tend to be less severe and support common interests.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE6.6_Identify_Resolutions_and_Improvements</IRI>
<Literal>The activities associated with identifying ways to address non-compliance or how to implement performance improvements. For non-compliance, this process may have one or a combination of outcomes, including

•terminating the contract
•collecting penalties
•updating the contract in terms of service levels, quality levels or terms and conditions
•continuing the business relationship as-is while making internal process, policy or business rule changes.

Litigation or mediation may be considered in this process. However, these practices are not supply chain processes.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE6.7_Select_Prioritize_and_Distribute_Resolutions</IRI>
<Literal>The activities associated with selecting, obtaining approvals for and prioritizing the appropriate issue resolutions and then distributing the selected resolution(s) to the appropriate processes or functions.
Litigation or mediation may be the result of decisions made in this process. However, these practices are not supply chain processes.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE7.1_Select_Scope_and_Organization</IRI>
<Literal>The activities associated with determining what part of the supply chain network will be assessed, thereby setting the scope of the project. Organizations that manage the supply chain network as a project structure will need to establish a project organization. Organization selection includes identifying and securing availability of a sponsor, stakeholders and data or information providers as well as selecting project team members.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>

```
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sE7.2_Gather_Input_and_Data</IRI>
    <Literal>The activities associated with identifying the objective of the supply
    chain and collecting the data required to describe or model the supply chain at
    the required level. Data collected should include facilities costs, capacities and
    locations; transportation costs, capacity and lead times; customer volumes,
    order frequency and order size; and customer locations.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sE7.3_Develop_Scenarios</IRI>
    <Literal>The activities associated with developing what-if scenarios to support
    different strategies and projections. Scenarios may be developed for different
    detailed strategies, requirements and potential internal or external changes.
    Activities include management interviews and external transportation and
    warehousing studies. Initial review of developed scenarios may result in
    rejection of the scenario or the decision to proceed to simulation.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sE7.4_Model_and_Simulate_Scenarios</IRI>
    <Literal>The activities associated with the development of models or simulation
    models to run what-if scenarios through a validation process. Simulation
    models may use automation, but conference room pilots or walk-throughs may
    also serve this purpose. The purpose of simulation is to validate the feasibility
    of each scenario and find possible network or process design flaws. Automated
    simulation tools may also predict the performance of the new network or
    processes by simulating the processing of large numbers of orders.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sE7.5_Project_Impacts</IRI>
    <Literal>The activities associated with estimating the effort, risks and results of
    implementing a scenario. Effort includes estimations of risks, the duration of
    funding, and the staff and skills required for implementing the scenario. Risks
    includes estimations of the impact on the value at risk for the supply chain.
    Results include changes that need to be made to the performance of the supply
    chain for all relevant metrics.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sE7.6_Select_and_Approve</IRI>
    <Literal>The activities associated with recommending and obtaining approvals
    for proposed supply chain network or configuration changes. This includes
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reviewing the what-if scenarios and their impact or benefit results with key stakeholders. The objective of this process is to identify the optimal solution and present this recommendation to the sponsor and stakeholders and obtain approval to develop the change program.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE7.7_Develop_Change_Program</IRI>
<Literal>The activities associated with developing the roadmap for the change program. This includes identifying the steps or projects required to implement changes to facilities, contracted parties, staffing, automation and processes. Specific changes are assigned to unique owners. This process includes reviewing the specific changes or projects with key stakeholders. The objective of this process is to obtain approval to launch change projects.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE7.8_Launch_Change_Program</IRI>
<Literal>The activities associated with coordinating, starting and monitoring the individual change projects. This includes supporting the establishment of change projects, coordinating launch dates and communicating reporting requirements. Steps also may include archiving the supply chain network or configuration project documentation for future reference and dissolving the project team. Dissolving the project team requires transferring the monitoring responsibility to the appropriate organizations.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE8.1_Monitor_Regulatory_Entities</IRI>
<Literal>The activities associated with identifying regulatory publications, subscribing to the publications, and receiving and reviewing the publications.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE8.2_Assess_Regulatory_Publications</IRI>
<Literal>The activities associated with reading, interpreting and researching policies, laws, rules and regulations. This includes determining if and how these regulatory requirements apply to a supply chain.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE8.3_Identify_Regulatory_Deficiencies</IRI>

```
    <Literal>The activities associated with identifying current and future regulatory
    requirements that are not being met or cannot be met using existing processes,
    business rules and policies. This includes notifying impacted organizations
    about the deficiency status.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sE8.4_Determine_Remediation</IRI>
    <Literal>The activities associated with identifying remediation alternatives;
    selecting and documenting processes, policies and business rules; and setting
    documentation requirements to remediate a deficiency.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sE8.5_Verify_and_Obtain_License</IRI>
    <Literal>The activities associated with verifying the remediation strategy with
    controlling entities and obtaining a license certifying compliance with the
    controlling entity’s laws, rules or regulations.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sE8.6_Publish_Remediation</IRI>
    <Literal>The activities associated with approving and implementing changes to
    processes, policies and business rules. This may include distributing
    certification documentation to relevant organizations in the supply
    chain.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sE9.1_Establish_Context</IRI>
    <Literal>The process of defining and documenting the objectives and internal
    and external scope for managing risk. This includes developing and maintaining
    an understanding of the internal and external relationships as well as the
    internal and external factors that influence the supply chain&apos;s ability to
    achieve its objectives and defining and maintaining a risk management
    organization made of stakeholders, a governance structure, procedures and a
    schedule.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sE9.2_Identify_Risk_Events</IRI>
    <Literal>The process of identifying, collecting and documenting all potential
    risk events that may prevent the organization from meeting its goals. This
    includes identifying sources of risk.
```

This process generates a comprehensive list of all risks that may disrupt the supply chain, including information about which processes in the supply chain will be directly and indirectly impacted by the occurrence of the risk event. A broad classification of risk types includes

- demand disruptions, such as customers going out of business
- supply disruptions, such as suppliers going out of business or having quality or performance issues
- environmental disruptions, such as floods, earthquakes, fires and storms
- financial disruptions, such as a lack of investors or credit availability
- fraud, theft and mismanagement
- labor disruptions, such as employee strikes or a lack of availability of qualified staff
- terrorism and cyberattacks.

The number of risks within these types may vary by industry.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sE9.3_Quantify_Risks</IRI>
<Literal>The process of collecting and documenting for each potential risk the causes, probability of occurrence and consequences. The standard metric for quantification of risk is value at risk (VaR):

VaR = Probability of Occurrence x Monetary Impact of Occurrence.

This process generates a comprehensive list of the monetary impact of all risks that may disrupt the supply chain. For certain types of risk events, probability information may be available through government agencies, insurance companies or research firms. The monetary impact is determined based on the projected monetary impact of each risk event on each supply chain. Here are some examples:

- For a single sourced material, the supplier going out of business means the product manufactured using this material cannot be produced until a new supplier has been identified, qualified and integrated into the supply chain. The monetary impact would be the loss of the projected revenue for these products during the qualification and integration process of a new supplier.

- For a dual-sourced material, one of the two suppliers going out of business means the product manufactured using this material can only be produced in the quantities the remaining supplier may be able to support until a new supplier has been identified, qualified and integrated or until the remaining supplier can support 100% of the project’s material needs.

Different risk events may have different types of monetary impacts, such as revenue reductions or cost increases.</Literal>

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</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sE9.4_Evaluate_Risks</IRI>
  <Literal>The process of prioritizing risk events by value at risk and determining
  for each risk whether mitigation actions are required or if the risk is
  acceptable.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sE9.5_Risk_Handling_Strategy</IRI>
  <Literal>The process of determining the actions required to eliminate, reduce
  or accept and monitor a risk. This can include creating, approving,
  communicating and launching the risk mitigation plan.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sM1.1_Schedule_Production_Activities</IRI>
  <Literal>Scheduling and managing the execution of the activities required to
  create a product or service. For a service, this can refer to scheduling value-
  adding activities. Scheduling typically is done in accordance with plans for the
  production of specific parts, products, formulations or services in specified
  quantities and the planned availability of required sourced products or services.
  This process includes sequencing and, depending on the factory layout, any
  standards for setup and run. In general, intermediate production or value-
  adding activities are coordinated prior to scheduling the operations needed to
  create a finished product or service.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sM1.2_Issue_Material</IRI>
  <Literal>The selection and physical movement of sourced or in-process
  products, including raw materials, fabricated components, subassemblies,
  required ingredients, and intermediate formulations or services, from a
  stocking or resource location to a specific point-of-use location. Issuing a
  product or resource includes the corresponding system transactions. The bill of
  materials or bill of service, routing information, and recipe or production
  instructions will determine the products to be issued to support the production
  operation(s).</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sM1.3_Produce_and_Test</IRI>
```

<Literal>The series of activities performed on sourced or in-process products or services to convert them from a raw or semi-finished state to a state of completion and greater value. This also includes processes associated with the validation of product performance to ensure conformance to defined specifications and requirements.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM1.4_Package_Product</IRI>
<Literal>The series of activities that containerize completed products for storage or sale to end users. Within certain industries, Package Product may include cleaning or sterilization. This process is not applicable to services.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM1.5_Stage_Product</IRI>
<Literal>The movement of packaged products or services into a temporary holding or waiting location to await movement to a delivery location. Products that are made to order may remain in the holding location to await shipment or transfer per the associated customer order. The movement to finished goods is part of the Deliver process. This process could also include the staging of resources for services.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM1.6_Release_Product_to_Deliver</IRI>
<Literal>Activities associated with the post-production documentation, testing or certification required prior to the delivery of a finished product or service to the end customer. Examples include assembly of batch records for regulatory agencies, laboratory tests for potency or purity, the creation of certificates of analysis or other quality records, and sign-off by the quality organization.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM1.7_Waste_or_Surplus_Management</IRI>
<Literal>Activities associated with collecting and managing waste or surplus produced during the value-add and testing processes. Waste and surplus can include scrap material, unused resources, and non-conforming products or deliverables.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>

<IRI>#sM2.1_Schedule_Production_Activities</IRI>
<Literal>Scheduling and managing the execution of the activities required to create a product or service.
Scheduling typically is done in accordance with plans to produce specific parts, products formulations or services in specified quantities and the planned availability of required sourced products or services. This process includes sequencing and, depending on the factory layout, any standards for setup and run. In general, intermediate production or value-adding activities are coordinated prior to scheduling the operations needed to create a finished product or service.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM2.2_Issue_Sourced_and_In-Process_Product</IRI>
<Literal>The selection and physical movement of sourced and in-process products, including raw materials, fabricated components, subassemblies, required ingredients, and intermediate formulations or services, from a stocking or resource location to a specific point-of-use location. This process includes the corresponding system transactions. The bill of materials or bill of service, routing information, and recipe or production instructions will determine the products to be issued to support the production operation(s).</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM2.3_Produce_and_Test</IRI>
<Literal>The series of activities performed on sourced or in-process products or services to convert them from a raw or semi-finished state to a state of completion and greater value. This also includes the processes associated with the validation of product performance to ensure conformance to defined specifications and requirements.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM2.4_Package</IRI>
<Literal>The series of activities that containerize completed products for storage or sale to end users. Within certain industries, Package may include cleaning or sterilization. Package is not applicable to services.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM2.5_Stage_Finished_Product</IRI>
<Literal>The movement of packaged products into a temporary holding or waiting location to await movement to a delivery location. Products that are

made to order may remain in the holding location to await shipment or transfer per the associated customer order. The actual move transaction is part of the Deliver process.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM2.6_Release_Finished_Product_to_Deliver</IRI>
<Literal>Activities associated with the post-production documentation, testing or certification required prior to the delivery of a finished product or service to the end customer. Examples include assembly of batch records for regulatory agencies, laboratory tests for potency or purity, the creation of certificates of analysis or other quality records, and sign-off by the quality organization.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM2.7_Waste_or_Surplus_Management</IRI>
<Literal>Activities associated with collecting and managing waste or surplus produced during the value-add and testing processes. Waste and surplus can include scrap material, unused resources, and non-conforming products or deliverables.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM3.1_Finalize_Production_Engineering</IRI>
<Literal>The engineering or configuration activities required after the acceptance of an order but before the deliverable or product can be produced. This may include generation and delivery of final drawings, specifications, formulas or part programs. In general, this is the last step in the completion of any preliminary engineering work done as part of the quotation process.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM3.2_Schedule_Production_Activities</IRI>
<Literal>Scheduling and managing the execution of the activities required to create a product or service. Scheduling typically is done in accordance with plans to produce specific parts, products formulations or services in specified quantities and the planned availability of required sourced products or services. This process includes sequencing and, depending on the factory layout, any standards for setup and run. In general, intermediate production or value-adding activities are coordinated prior to scheduling the operations needed to create a finished product or service.</Literal>
</AnnotationAssertion>

<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM3.3_Issue_Sourced_and_In-Process_Product</IRI>
<Literal>The selection and physical movement of sourced and in-process products, including raw materials, fabricated components, subassemblies, required ingredients, and intermediate formulations or services, from a stocking or resource location to a specific point-of-use location. This process includes the corresponding system transactions. The bill of materials or bill of service, routing information, and recipe or production instructions will determine the products to be issued to support the production operation(s).</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM3.4_Produce_and_Test</IRI>
<Literal>The series of activities performed on sourced and in-process products or services to convert them from a raw or semi-finished state to a state of completion and greater value. This also includes the processes associated with the validation of product performance to ensure conformance to defined specifications and requirements.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM3.5_Package</IRI>
<Literal>The series of activities that containerize completed products for storage or sale to end users. Within certain industries, Package may include cleaning or sterilization. Package is not applicable to services.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM3.6_Stage_Finished_Product</IRI>
<Literal>The movement of packaged products into a temporary holding or waiting location to await movement to a finished goods location. Products that are engineered to order may remain in the holding location to await shipment per the associated customer order. The actual move transaction is part of the Deliver process.
This process could also include the staging of finished resources for services.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sM3.7_Release_Configured_Product_to_Deliver</IRI>
<Literal>Activities associated with the post-production documentation, testing or certification required prior to the delivery of a finished product or service to

```
    the end customer. Examples include assembly of batch records for regulatory
    agencies, laboratory tests for potency or purity, the creation of certificates of
    analysis or other quality records, and sign-off by the quality
    organization.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
   <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
   <IRI>#sM3.8_Waste_Surplus_Management</IRI>
   <Literal>Activities associated with collecting and managing waste/surplus
    produced during the value-add and test process including scrap material,
    unused resources and non-conforming products/deliverables.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
   <AnnotationProperty abbreviatedIRI="rdfs:comment"/>

    <IRI>#sP1.3_Balance_Supply_Chain_Resources_with_Supply_Chain_Requiremen
    ts</IRI>
   <Literal>The process of identifying and measuring the gaps and imbalances
    between demand and resources in order to determine how to best resolve the
    variances through marketing, pricing, packaging, warehousing, outsourcing
    plans or some other action that will optimize service, flexibility, costs, assets or
    other supply chain inconsistencies in an iterative and collaborative
    environment. Includes developing a time-phased course of action that commits
    supply chain resources to meet supply chain requirements.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
   <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
   <IRI>#sP1.4_Establish_and_Communicate_Supply_Chain_Plans</IRI>
   <Literal>The establishment and communication of courses of action throughout
    the appropriate time-defined planning horizon and interval that represent a
    projected appropriation of supply chain resources to meet supply chain
    requirements.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
   <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
   <IRI>#sP2.3_Balance_Product_Resources_with_Product_Requirements</IRI>
   <Literal>The process of developing a time-phased course of action that commits
    resources to meet requirements.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
   <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
   <IRI>#sP2.4_Establish_Sourcing_Plans</IRI>
```

```
  <Literal>The establishment of courses of action throughout specified time
  periods that represent a projected appropriation of supply resources to meet
  sourcing plan requirements.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>

  <IRI>#sP3.3_Balance_Production_Resources_with_Production_Requirements</
  IRI>
  <Literal>The process of developing a time-phased course of action that commits
  creation and operation resources to meet creation and operation
  requirements.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sP3.4_Establish_Production_Plans</IRI>
  <Literal>The establishment of courses of action throughout specified time
  periods that represent a projected appropriation of supply resources to meet
  production and operating plan requirements.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>

  <IRI>#sP4.3_Balance_Delivery_Resources_and_Capabilities_with_Delivery_Requ
  irements</IRI>
  <Literal>The process of developing a time-phased course of action that commits
  delivery resources to meet delivery requirements.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sP4.4_Establish_Delivery_Plans</IRI>
  <Literal>The establishment of courses of action throughout specified time
  periods that represent a projected appropriation of delivery resources to meet
  delivery requirements.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sP5.1_Assess_and_Aggregate_Return_Requirements</IRI>
  <Literal>The process of identifying, evaluating and considering as a whole with
  constituent parts all sources of demand for the return of a product.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sP5.3_Balance_Return_Resources_with_Return_Requirements</IRI>
```

```
    <Literal>The process of developing plans that make it possible to commit return
    resources or assets to satisfy return requirements.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sP5.4_Establish_and_Communicate_Return_Plans</IRI>
    <Literal>The establishment and communication of courses of action throughout
    specified time periods that represent a projected appropriation of required
    return resources or assets to meet return process requirements.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS1.1_Schedule_Product_Deliveries</IRI>
    <Literal>Scheduling and managing the execution of the individual deliveries of
    products against existing contracts or purchase orders. The requirements for
    product releases are determined based on a detailed sourcing plan or other
    types of product pull signals</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS1.2_Receive_Product</IRI>
    <Literal>The process and associated activities of receiving products to contract
    requirements.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS1.3_Verify_Product</IRI>
    <Literal>The process and actions required to determine product conformance
    to requirements and criteria.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS1.4_Transfer_Product</IRI>
    <Literal>The transfer of accepted products to the appropriate stocking location
    within the supply chain. This includes all of the activities associated with
    repackaging, staging, transferring and stocking products. For services, this is
    the transfer or application of a service to the final customer or end
    user.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS1.5_Authorize_Supplier_Payments</IRI>
```

```
    <Literal>The process of authorizing payments and paying suppliers for product
    or services.  This process includes invoice collection, invoice matching and the
    issuance of checks.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS2.1_Schedule_Product_Delivers</IRI>
    <Literal>Scheduling and managing the execution of the individual deliveries of
    products against the contract. The requirements for product deliveries are
    determined based on a detailed sourcing plan. This scheduling process includes
    all aspects of managing the contract schedule, including prototypes,
    qualifications and service deployment.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS2.2_Receive_Product</IRI>
    <Literal>The process and associated activities of receiving products to contract
    requirements.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS2.3_Verify_Product</IRI>
    <Literal>The process and actions required to determine product conformance
    to requirements and criteria.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS2.4_Transfer_Product</IRI>
    <Literal>The transfer of accepted products to the appropriate stocking locations
    within the supply chain. This includes all of the activities associated with
    repackaging, staging, transferring and stocking products. For services, this is
    the transfer or application of a service to the final customer or end
    user.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS2.5_Authorize_Supplier_Payment</IRI>
    <Literal>The process of authorizing payments and paying suppliers for
    products or services. This process includes invoice collection, invoice matching
    and the issuance of checks.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS3.1_Identify_Sources_of_Supply</IRI>
```

```
    <Literal>The identification and qualification of potential suppliers capable of
    designing and delivering products that will meet all of the required product
    specifications.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS3.2_Select_Final_Supplier_and_Negotiate</IRI>
    <Literal>The identification of the final supplier(s) based on the evaluation of
    requests for quotes and supplier qualifications and the generation of a contract
    defining the costs and terms and conditions of product availability.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS3.3_Schedule_Product_Deliveries</IRI>
    <Literal>Scheduling and managing the execution of the individual deliveries of
    products against the contract. The requirements for product deliveries are
    determined based on a detailed sourcing plan.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS3.4_Receive_Product</IRI>
    <Literal>The process and associated activities of receiving products to contract
    requirements.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS3.5_Verify_Product</IRI>
    <Literal>The process and actions required to determine product conformance
    to requirements and criteria.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS3.6_Transfer_Product</IRI>
    <Literal>The transfer of accepted products to the appropriate stocking location
    within the supply chain. This includes all of the activities associated with
    repackaging, staging, transferring and stocking products.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#sS3.7_Authorize_Supplier_Payment</IRI>
    <Literal>The process of authorizing payments and paying suppliers for product
    or services.  This process includes invoice collection, invoice matching and
    issuance of checks.</Literal>
  </AnnotationAssertion>
```

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<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sSR1.1Identify_Defective_Product_Condition</IRI>
  <Literal>The process in which the customer utilizes planned policies, business
  rules and inspections of product operating conditions as criteria to identify and
  confirm that material is excess to requirements, needs an upgrade or is
  otherwise defective.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sSR1.2_Disposition_of_Defective_Product</IRI>
  <Literal>The process in which the customer determines whether to return the
  defective item and identifies the appropriate source to contact for a return
  authorization. This also applies to items that are being returned for
  upgrade.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sSR1.3_Request_Defective_Product_Return_Authorization</IRI>
  <Literal>The process of a customer requesting and obtaining authorization for
  the return of a defective product or a product being returned for upgrade from
  the last known holder or the designated return center. In addition, the customer
  and the last known holder or the designated return center should discuss
  enabling conditions such as return replacement or credit, packaging, handling,
  transportation, and import and export requirements to facilitate the efficient
  return of the defective or outdated product.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sSR1.4_Schedule_Defective_Product_Shipment</IRI>
  <Literal>The process in which the customer develops the schedule for a carrier
  to pick up the defective product for delivery to the last known holder or the
  designated return center. This also applies to items that are being returned for
  upgrade. Activities include selecting the carrier and rates, preparing the item
  for transfer, preparing scheduling documentation, and managing overall
  scheduling administration.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#sSR1.5_Return_Defective_Product</IRI>
  <Literal>The process in which the customer packages and handles the defective
  product or the product being returned for upgrade in preparation for shipping
  in accordance with predetermined conditions. The customer then transfers the
  product to the carrier, who physically transports the product and its associated
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documentation to the last known holder or the designated return
center.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sSR3.1_Identify_Excess_Product_Condition</IRI>
<Literal>The process in which the customer utilizes planned policies, business
rules and product inspection as criteria to identify and confirm that material is
in excess of the current requirements. This process also can be applied to
products that are unwanted because of size, style, color or other customer
preferences.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sSR3.2_Disposition_of_Excess_Product</IRI>
<Literal>The process in which the customer determines whether to return the
excess material and identifies the designated return center to contact for a
return authorization. This process also can be applied to products that are
unwanted because of size, style, color or other customer preferences.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sSR3.3_Request_Excess_Product_Return_Authorization</IRI>
<Literal>The process of a customer requesting and obtaining authorization
from the designated return center for the return of excess product. In addition,
the customer and designated return center should negotiate enabling
conditions such as return credit or cash discount, packaging, handling,
transportation, and import and export requirements to facilitate the efficient
return of the excess product. This process also can be applied to products that
are unwanted because of size, style, color or other customer
preferences.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>
<IRI>#sSR3.4_Schedule_Excess_Product_Shipment</IRI>
<Literal>The process in which the customer develops the schedule for a carrier
to pick up the excess product. Activities include selecting the carrier and rates,
preparing the item for transfer, preparing scheduling documentation, and
managing overall scheduling administration. This process also can be applied to
products that are unwanted because of size, style, color or other customer
preferences.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
<AnnotationProperty abbreviatedIRI="rdfs:comment"/>

```
<IRI>#sSR3.5_Return_Excess_Product</IRI>
<Literal>The process in which the customer packages and handles the excess
product in preparation for shipping in accordance with predetermined
conditions. The customer then transfers the product to the carrier, who
physically transports the product and its associated documentation to the
designated return center. This process also can be applied to products that are
unwanted because of size, style, color or other customer preferences.</Literal>
</AnnotationAssertion>
</Ontology>


<!-- Generated by the OWL API (version 4.5.9.2019-02-01T07:24:44Z)
https://github.com/owlcs/owlapi -->
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14. ABSTRACT
Information is crucial to supply chain performance because it is used to make decisions and trigger actions. Organizations across world-class supply chains increasingly use information technology to analyze and process supply chain data. However, supply chain management lacks a common language, making information exchange difficult. An ontology can provide a standardized framework that organizes a given knowledge domain. This research proposes a common language for developing a supply chain ontology that can be built into a basic formal ontology understood by both humans and computers. According to current research, an established and widely used supply chain framework is a good starting point for developing a supply chain ontology. Many researchers recommend using the Supply Chain Operations Reference (SCOR) Model. This framework is translated into a software package that generates a Web Ontology Language (OWL), which can be used by information technology. This research analyzes the need for a standard supply chain language and identifies a framework to use as a starting point for developing an ontology. Using SCOR 12.0 as the framework, an XML/OWL based model is developed, which can be used by information technology to improve information exchanges between supply chain partners. Supply chain practioners will benefit from anontology built on the SCOR 12.0 framework that has been digitalized to support information technology professionals and enable supply digital supply chains.

15. SUBJECT TERMS

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