Developing a Logistics Ontology for Natural Language Processing

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Abstract: - The business area requires the presence of Supply Chain services, to respond to the constantly evolving requirements. Supply chains are dynamic networks that include a continuous flow of processes, starting with the supplier and ending with the customer. For effective supply chain management, a conceptual understanding of the knowledge underlying this field is of utmost importance. On the other hand, ontologies are considered one of the most appropriate ways of representing knowledge and valuable tools for decision-making situations. The purpose of this paper is to present an ontology created to identify the common concepts of supply chain management systems, with the ultimate goal of supporting and promoting Natural Language Processing technologies through the representation of terminological knowledge for this specific field.

Key-Words: - Ontology, logistics, knowledge management, knowledge representation, Natural Language Processing, computational lexicography.

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1 Introduction

From the 1960s onwards, business activity has been inextricably linked to the concept of Logistics [1], whose role and importance have been expanded and upgraded considering the development of business research, the leapfrog development of technology, and ever-increasing competition. In fact, in recent decades, it has become increasingly clear that the business area can no longer meet the ever-evolving requirements without the presence of Supply Chain (SC) services. As the role and the importance of Logistics expands and upgrades and as the demands for rapid movement of goods to serve consumers are constantly increasing, the existence of a knowledge system is also required, [2], [3], which will help companies to conceptually understand the basic structural elements of their supply chain, to achieve the necessary efficiency and sustainability, the market promotion, the profit growth and the satisfaction of all the stakeholders.

On the other hand, in the last decades, research in the field of Artificial Intelligence and Natural Language Processing has focused on the implementation of conceptually structured Knowledge-Based Systems (KBS) that use ontologies as a basis for the semantic integration of information, due to the scientific certified usability of the ontological structuring of data in the Semantic Web, [4], [5]. Ontology, as a formal, explicit specification of a shared conceptualization, that can be exchanged between humans and application systems [6], is considered one of the most appropriate ways of representing linguistic knowledge, as it allows it to be expressed in a systematic way a wide range of semantic relations, the safe use of which can lead to drawing inferences [7]. Consequently, both the semantic and the morpho-syntactic information contained within each word can be encoded with great precision with the help of ontologies, and, as a result, this method of representing terminological knowledge can contribute to meeting the modern requirements for services of intelligent modeling, analysis and use of online information [8], especially in the area of the SC, where there is an absence of conceptual schemes.

2 Description of the Problem

In [8], the authors, attempt to implement an "intelligent" electronic conceptual dictionary of the Modern Greek Language, which will be able to constitute an expandable repository of knowledge and information with possible applications in various fields (linguistic and cross-linguistic research, educational applications, interconnection with other dictionaries and their enrichment, use for improving search engines, etc.) and choose as its basic domain the description of concepts related to the field of industry, where, while the development of ontological schemas was almost non-existent during the previous decade [9], the last years (2022-2023) have seen significant efforts to solve the problem due to the ever-increasing demands. At the same time, it is observed that the area of the SC is characterized by insufficient engagement and a complete absence of conceptual descriptions and ontological representation of the concepts. The search in the Hellenic Academic Libraries for taxonomies and ontologies in the Greek language related to this field did not return any results, in contrast to the English language, for which thirty-six (36) results were returned for taxonomies and one hundred forty-one (141) results were returned for ontologies. Regarding search terms, the terms: "Εφοδιαστική", "Εφοδιαστική Αλυσίδα", "Ταξινομία" and "Οντολογία" were used as keywords for the Greek language and the terms "Logistics", "Supply Chain", "Taxonomy" and "Ontology" respectively were used for the English language. Also, on the website of ELETO (Hellenic Terminology Society) no glossary related to the Supply Chain sector was found, although some terms related to information technology and mainly to the telecommunications standards of the SC are found in the terminological bases INFORTERM and TELETERM, respectively.

Supply Chain Management has become increasingly difficult due to the development of technology and the increase in the complexity of interactions and flow mechanisms within its structures, they deemed it necessary to specialize their research and turn to conceptual models and ontologies to identify the concepts and the semantic relationships of supply chain networks. Thus, in this paper, they present their attempt to design a new ontology for the conceptual understanding of Supply Chain Management, from which benefits will arise in two scientific fields:

- Supply Chain;
- Computational Lexicography.

In other words, the new ontology will cover the gap that exists in both of these areas, in conceptual and mainly ontological forms of knowledge representation, especially for the Greek language. Therefore, it will contribute:

- to occupy a key position for the lexical base of the Greek Ontology Lexicon developed by the authors in [8], which aims - through the connection with hierarchical-ontological relationships of the morphological, syntactic, and semantic information of the words and under the light of a standard and standardized organization and coding of data coming from structured and semi-structured information sources - at the extraction and production of sound knowledge;
- in the optimization of the operations circle of the SC, to which the knowledge system under development will lead through the achievement of sound strategy and decision-making that the semantic integration will offer.

3 Modelling Supply Chain

As the authors in [10] point out, although there are many definitions for the term "Supply Chain" in the international literature, depending on the perspective and the purpose of the research, all of them converge in that the SC is a process that runs through a flow of materials and a reverse flow of information. In [11] it is argued that the SC is a linked series of activities, a system whose constituent parts include material suppliers, production facilities, distribution services, and customers linked together by the "forward" flow of materials and the "backward" flow of information. In particular, SC is an integrated process of planning, applying, and controlling essential processes [12], a network of connected entities [13] that produces and adds value in the form of products or services in the hands of the end consumer, [14], [15], supporting him even after the sale of the products to preserve them [16] (see: Green Logistics, Reverse Logistics, Closed-loop Supply Chain). Given the above, the goal of all companies is sound and sustainable Supply Chain Management, a subset of which is Logistics (various opinions have been expressed regarding the relationship between Supply Chain and Logistics; for these opinions, [17], [18], which plans, implements, and controls the efficient and effective normal and reverse flow and storage of products, services, and related information from point of origin to point of consumption to meet requirements of customers [19], who can create "value" themselves, turning the Supply Chain into a Demand Chain.

Since SC is an area that includes procurement and purchasing management, materials and production management, transportation management, inventory and storage management, distribution, and customer service, including in recent years additional aspects of business activity such as recycling, product life cycle, environmental protection, and sustainability (in extended supply chain networks), it is clear that it constitutes a "value chain", [20], that has been extended during its completion into a "value network" (value network or value web), representing a new active type of business model. According to [21], Supply Chains are networks that consist of connected and interdependent organizations that work together in a collaborative climate to control, direct, and improve the flow of materials and information from suppliers to end users. Therefore, in the context of the creation of a scheme of interpretation, modeling, and simulation of this network called SC, which way of representing and modeling it would be more effective for analyzing its concepts and especially the way they interact than an ontology, since the latter is in essence, a semantic network that can capture through nodes the relationships that exist between the interdependent entities (processes, activities, operations, etc.) of the Supply Chain.

Even though the choice of ontology as a knowledge representation and modeling method is obvious and justified due to its usefulness in the wider field of knowledge representation, the concerns raised at this stage of the research are diverse and concern both the structure and the content of the ontology. The first consideration concerns whether existing ontologies that have been developed in the field of SC should be extended or whether a new ontology should be created from scratch. The second consideration concerns the decisions that need to be made, for example, about which SC concepts should be approached for a complete analysis of the field, which SC components should be considered primary or secondary, how these elements should be structured, so that there is a more complete structure of the SC, from which point of view the SC should be approached as a unified whole, etc.

Certainly, the review of the relevant literature contributed to the resolution of the above concerns. The authors of this paper, starting the research for the design of the new ontology, studied sixty-seven (67) pre-existing ontologies (all in the English language, in the absence of ontologies in Greek), aiming at the unification of elements and the integration of systems to optimize each field in which the ontology will be used. In [10], they concluded that the models that have been developed for the SC are certainly an intersection in the effort to model business operations and delineate a good basis for businesses to engage in Logistics processes, but they lack an adequate formulation of appropriate semantics and terminology to describe all the different functions of the SC. All work related to SC ontology focuses on the organization and structure of human knowledge about the supply chain and not on understanding the reality of supply chains, with the result that all the methodological approaches adopted are far removed from the reality of SC itself. The existing ontologies partially focus on Logistics concepts (e.g., process, delivery, and return), without any comprehensive view of the entire field. Consequently, a static and limited perspective on the supply chain field prevails, while detailed analysis is found only at the strategic level, [22]. The ontology's content is reduced to simple terminological problems [22], while at the same time inconsistent and confusing terminology of the ontology structures, as well as a lack of ontological clarity, is observed. Finally, there is a lack of integration of the existing ontologies, with the result that each ontology describes the concepts differently. This lack inevitably leads to incompatible interpretations and uses of the knowledge resulting from inter-company transactions. Thus, the creation of a new ontology in the field of SC, and in particular in internal logistics where there is no completeness, responds to the absence of a classified comprehensive presentation of the basic concepts of the SC, while the necessity of unifying and integrating all knowledge requires the creating the ontology from scratch.

4 A New Ontology

The ontology proposed in this paper is a supply chain simulation ontology, the design of which was a very demanding task, as intensive efforts, thorough research, appropriate manipulations, and various considerations were needed to make decisions about the choice of modeling technique, in order to render the exact image of the field. The decisions made were shaped by the available modeling techniques, which in turn required many efforts to develop accurate models that would achieve the intended use and its benefits. Precisely because its use concerns a variety of domains and functions, it bears the name Multi Solution Ontology (MSO).

Based on the conclusions obtained from the literature review, the authors of this paper modeled the flow of materials and information within the supply chain, capturing all its driving forces and documenting their dynamic behavior. In particular, they attempted to classify basic concepts from various perspectives and investigated their scope within the SC, trying to unify previous knowledge and integrate most efficiently all the data of previous ontologies. The presented ontology is essentially an application ontology, because - according to the division of ontologies based on [23] - it provides the vocabulary for a domain, which is none other than the SC, as well as a specific task which is none other than logistics operations covering a wide range of tasks.

4.1 Implementation Language and Tool

Regarding the language and its implementation tool, both the literature review and the ontology requirements drive the choice of the Protégé platform and the ontology language OWL (Web Ontology Language). As emphasized by the authors in [8], Protégé is a widespread open-source tool that has expressiveness, provides the ability to import-export data in several languages (Flogic, Jess, OIL, XML, RDF, PROLOG, OWL, etc.) as well as to change the coding language, has an inference engine and an interface for the SWRL (Semantic Web Rule Language), which is a language that combines OWL with RuleML [24], works with Description Logic Reasoners to draw inferences, supports the visualization of ontologies (via OntoViz and OntoGraph), contains ontology libraries, and offers capabilities to import, transfer, store and merge ontologies (via Anchor-Prompt plugin) as well as validity check (via FACT and PA1 plugins). It is a tool with an easy-to-use and interactive graphical environment that stands out for its scalability and extensibility, it is constantly evolving and has new software versions. Regarding the OWL language [25], it is an easy-to-use language that has expressiveness, supports semantic definitions and logical inference mechanisms that allow the production of knowledge that has not been explicitly stated (implicit knowledge), as it offers a more powerful syntax than RDF(S) and more powerful logic-based semantics, and enables a range of descriptive applications. Also, W3C (World Wide Web Consortium) proposes OWL as an official ontology language. Therefore, both the Protégé platform and the OWL language are the most appropriate means for implementing the ontology, especially given that most of the ontology creators reviewed for this task are the supporters of these means, [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39].

4.2 Structure and Organization

Regarding the methodology for the design of the ontology, the seven (7) steps proposed in [40] were followed in the first phase, namely:

(1) The scope and the application domain of the ontology are defined, as described below in this paper.

(2) The SCOR model (Supply Chain Operations Reference model) is one of the most well-known business reference models [41], [42], which provides terminology and standardized procedures. The SCOR model at the level of strategy is based on five basic entities: (i) plan, (ii) make, (iii) deliver, (iv) return, and (v) source [10]. The possibility of reusing already existing ontologies, especially those based on the SCOR model and having common points, was considered, but without following such a solution, mainly because the terms in the ontology will not only be in English but also in Greek, which adds one more reason to create a new ontology from scratch.

(3) A list of the most important, common, and widely used terms in the supply chain field (simple and complex, Greek and English) was created to be used in the ontology (about 3,000). We derived these terms from Greek and foreign literature but also from Open Data in the Supply Chain area. Regarding the terms that come from the Greek literature, most of them come from [43], while most open data terms come from [44].

(4) The classes and the hierarchy of the classes, that is the entities, the objects, and their hierarchy were defined with a combination of bottom-up and top-down approaches. Classes represent the concepts related to a field or some tasks, which are usually organized in some taxonomic system. An entity is a thing that exists either physically or logically. It can be a physical object, such as a factory or a truck (they exist physically), an event, such as a sale of a product or a car service, or an idea, such as a transaction or a customer order (they exist logically - as a concept). Entities of the physical world can in turn be deconstructed into objects. Object is a separate entity, which tries to model and approach as best as possible the physical world, [45].
(5) The relations between the objects, i.e., the object's properties, were defined.
(6) The characteristics of the object properties, and the data properties (facets of slots), were defined.
(7) Individual instances of classes in the hierarchy were created and object property assertions were added. Object or relationship instances represent specific elements with specific values. For example, the object "company" can have as its instances: "CompanyA", "CompanyB", "CompanyC" etc.

At the same time, considerations were recorded for (i) defining the rules and (ii) setting the defined classes, which will be completed in the next phase with the completion of the ontology.

In the first (1st) step, aiming to identify the entities, the authors of this paper were inspired by the questions raised by J. Zachman about the enterprise architecture in the Zachman Framework, [46]: "What?", "How?", "Who?", "Where?", "When?", and "Why?" and they tried to answer the following indicative questions:

- *"What?": What* are the concepts involved in the Supply Chain?
- *"How?": How* does the flow of materials and information in the Supply Chain take place? *How* are processes carried out in the Supply Chain? *How* will the business make money?
- *"Who?": Who* is involved in Supply Chain activities? *Who* are the human resources in the Supply Chain?
- *"Where?": Where* do the various activities of the Supply Chain take place?
- *"When?": When* (start and end time) do the various activities of the Supply Chain take place?
- *"Why?": Why* (with what motivation and for what objective) has the Supply Chain been created? *Why* is the consumer willing to give money?

One of the ways to define the domain of ontology is to outline a list of questions, which an ontology-based knowledge base should be able to answer. These questions are called Competency Questions, [47]. Thus, based on the above questions, they initially formulated the following indicative "competency questions":

(1) What is the domain that the ontology will cover?
(2) Why will we use the ontology?
(3) What does the concept of "Supply Chain" include?
(4) What is the concept of "Value" in the Supply Chain?
(5) What does the concept of "Extended Supply Chain" (Green Supply Chain, Reverse Supply Chain, Closed Loop Supply Chain) include?
(6) What is the importance of "Time" in the Supply Chain?
(7) What types of "flows" do we distinguish in the Supply Chain?
(8) What is the position of the "Product" in the Supply Chain?
(9) What is the importance of "Inventory" for the Supply Chain?
(10) What is the importance of the "Order" for the Supply Chain?
(11) What processes (activities, procedures, operations) of the Supply Chain are related to its flows?
(12) Which resources (natural, human, financial, and technological) are required to implement these processes?
(13) Who are the stakeholders involved in the Supply Chain?
(14) How (means of transport, distribution networks, etc.) will the goods be transported from one location in the chain to another?
(15) Which means of transport is best to use and when? What will be the route and with what load?
(16) How is the information used and what systems are required? How much data

should be collected and how much should be shared on-chain?

(17) Which management strategy for each type of supply chain flow should be followed depending on the prevailing circumstances?

(18) How should decisions be made at a strategic, operational, and tactical level to plan and execute processes at the various stages of logistics (e.g., procurement, production, transport, warehousing, delivery, customer service)?

(19) Based on which indicators should the control and the evaluation of the Supply Chain be done?

(20) How will the environment be protected by Supply Chain activities?

(21) What problems does the Supply Chain face?

(22) What are the objectives of the Supply Chain?

(23) Is it possible to integrate the Supply Chain?

Of course, an ontologically defined knowledge base cannot be described only by a list of questions it can answer, but also by the questions it cannot answer, and more precisely by the questions it has difficulty answering (especially in supply chain integration issues), the research will shed light on them when it is completed and its results will be evaluated in practice.

In continuation, considering that the above questions should be answered, a new ontology was designed focusing deeper and more detailed:

- on the structural elements of SC, such as the individual stages (procurement, production, transport, warehousing, delivery, customer service), the processes, activities, operations, procedures, and flows implemented throughout its network, information technologies, telecommunications, and telematics, its actors, the strategy followed at each stage, etc.;
- in the way all these are connected to each other.

Thus, in the fourth (4th) step, the basic classes and the hierarchy of the classes, that is, the entities, the objects, and their hierarchy, were defined with a combination of bottom-up and top-down approaches. More specifically, the basic classes of the presented ontology are six (6): *Supply Chain, Flow, Product, Process, Stakeholders, and Purpose.* Their meaning and relationships are described below, while the main entities and their relationships are schematically shown in Figure 1 and Figure 2 in Appendix.

The *"Supply Chain"* entity is conceptually linked to the "Supply Chain Management" entity, which has as its sub-class the "Logistics" entity. The latter has as its sub-classes the entities "Warehousing" and "Transfer". In addition, the "Supply Chain" is associated with the "Process" entity, as it is by definition a process, it is associated with the "Flow" entity, as it implements the flow within the SC network and, of course, it is associated with the "Planning" entity, as it requires proper design for its proper functioning. It is also associated with the "Product" entity since the product is a prerequisite for the existence of the SC itself, as well as with the "Stakeholders" entity since those involved in the various stages of the chain carry out the processes that constitute it. Finally, the "Supply Chain" entity is associated with the "Purpose" entity, since the flow of the entire SC satisfies a specific purpose.

The *"Flow"* entity is implemented by the "Supply Chain" and, consequently, by the "Process" that is performed, based on the "Product" (flow of materials), directed by the "Stakeholders" in the SC (through human resource flow) and its "Integration of Flow Management" is a core "Purpose" of Logistics. The "Flow" entity includes eight (8) sub-classes: resource flow, time flow, material flow, service flow, value flow, human resource flow, information flow, and financial flow. Of course, these flows are interdependent for the entire supply chain system to function successfully.

The *"Process"* entity refers to the methodical series of actions that lead to a certain result and are performed in various stages by each involved company. This entity that implements the "Flow" entity is identified with the entity of "Value-added Processes" (Figure 2 in Appendix) and has as its sub-classes the "Activities" (i.e., the set of actions of a group of people related to a specific field at a time) and the "Procedures" (i.e., the process of performing the set of operations) carried out for the implementation of the movement of products from the supplier to the consumer. It is also directly related to the "Product" entity since this is its main object, it is related to the "Stakeholders" entity since they execute the processes, and it is the entity through which the "Purpose" entity is implemented.

The *"Product"* entity refers to all the information related to the design of the product, its structure (each product has its parts and its special characteristics), its cost, material information, inspection data, durability (especially for perishable products), technical support and maintenance information and, more generally, the physical and functional characteristics of the product. The "Product" is the basic subject of the "Process" entity and the "Supply Chain" entity is based on it, as without it none of the other entities could exist.

The *"Stakeholders"* entity includes as a concept all those involved in the SC. Thus, it has as its sub-classes the entities: "supplier", "manufacturer", "transporter", "service provider/3PL", "distributor", "trader", and "customer". All these entities, except the "customer" entity, are sub-classes of the "Partners" entity. The "Stakeholders" entity is conceptually linked to the "Process" entity, as human resources carry out the processes. Furthermore, this entity implements the "Human Resource Flow", manages the "Product" at each stage, and leads to the achievement of the "Purpose" of the SC.

The *"Purpose"* entity refers to the ultimate purpose of the SC which is the upgrading of the consumer's quality of life, which is achieved by satisfying the customer, increasing profit, and reducing costs. This entity is a sub-class of the "Planning" entity, as they are the "Strategy", "Control" and "Measures" entities. The "Purpose" entity is linked to the "Integration of Flow Management" entity, as through it - which is a process - it can be achieved more easily. After all, all processes lead to the fulfillment of the purpose of Logistics.

It is worth noting that the main axis of data modeling is the flows of the Supply Chain, which are often treated in the literature as the fundamental characteristics of its various stages. Based on the flows, many researchers have tried to interpret, model, or even simulate the operation of supply chains in general. Thus, the upper entity in the ontology is the "Flow" entity, which interacts with all other entities. The complexity and variety of relationships of the Flow entity with other entities are captured in the Protégé platform graph in Figure 3 (Appendix). This minimal sample of the complex relationships in Figure 3 (Appendix) demonstrates that ontology as a knowledge representation model is essentially a logically organized system, a set of things, concepts or processes that are logically interdependent, so that any change in one of them to affect one or all of the others, and which form a logically structured whole.

In other words, *the set of entities* (classes and subclasses) that are linked based on specific rules to their objects and to the instances of their objects, which in turn are linked to their properties and the characteristics of the object's properties, i.e., the data properties, *is a system*. However, *the Supply Chain is also a system*, since suppliers, manufacturers, distributors, retailers, and customers cooperate and are interdependent, while materials flow from suppliers to customers and information flows both ways. Therefore, it becomes clear that one of the goals of the research is achieved, i.e., to prove that Supply Chain as a system could not be described and represented better than only through an ontology.

4.3 Utility and Applications

The ontology described in this paper was created on the occasion of the implementation of an electronic Greek Ontology Dictionary (GOD). It is, that is, one of the basic domains of a broader ontological organization of concepts in the context of creating a lexical database using the Protégé platform and the OWL, [8]. However, it can be used as a tool for a variety of functions in both Natural Language Processing and Business. A guideline in its design was the aim of the authors to create an ontology that will be able to fulfill various purposes, hence the name "Multi Solution Ontology". Initially, it will form the lexical database of GOD. At the same time, as a core ontology, it can be used as a basis for promoting communication (communication purpose), and facilitating interoperability between individuals and organizations that use different standards. Individuals and organizations will benefit from an integrated environment (integration purpose) that will facilitate supply chain/logistics services. Another one of its goals is to highlight the role of ontology in creating value and competitive advantage for businesses and, by extension, for the overall SC system. With its use, optimization mechanisms of SC and information flows will be created with the presentation, classification, and investigation of the established, but also the most modern concepts. For example, in Figure 4 (Appendix), it is shown how the user of the ontology is guided through a flow diagram to perform the task of "refill picking area". This means that all supply chain processes are captured and interpreted in such a way that the user is able not only to understand them in natural language but also to execute them properly, should he/she be called upon to do so. In this context, it is also possible to be some interactions between the ontology and SAP (Systems, Applications, and Products) software, which provides solutions for business accounting, Enterprise Resource Planning (ERP), Supply Chain Management (SCM), human resources, and other business processes and it is widespread worldwide, especially in Jordan, where it is used by 21 enterprises out of 56, [48]. The results of these interactions would be very useful since the ontology can be used to understand and describe the data structure used in applications such as SAP.

In addition, given that this ontology has considered the three main factors that currently form the structure of the Supply Chain:

- the customer-centric philosophy of businesses;
- the IT and telecommunications technology;
- the protection of the consumer and the environment, can contribute to the building and efficient operation of a value-added "integrated supply chain", which is the key to obtaining a strategic sustainable competitive advantage.

It can also be used as a basis for engineering purposes, providing support for the development of software solutions such as WMS or TMS used in logistics to manage the storage or transportation activities that characterize chain supply.

5 Conclusion – Future approaches

The authors of this paper, aiming to capture and represent key concepts of the Supply Chain, implemented an ontology from scratch, intending to be effective and efficient as well as having clarity and objectivity, completeness and coherence (coherence). The effectiveness of the ontology in representing SCM concepts will be evaluated in the future. This also entails comparing the ontology against existing frameworks and conducting experiments that will include testing the ontology in simulated supply chain scenarios or real-world applications to assess its effectiveness in modeling and simulating supply chain processes. Furthermore, the main concern of the authors from now on will be to make this ontology a valuable tool for decision-making situations in the Supply Chain. Business intelligence methods and processes will become objects of research to design systematic decision-making processes (decision trees) for the supply chain as if they were control rules for dynamic systems. During the operation phase of the system as a Decision Support System, the problem elements can be entered by the user, and then the answer can be given through a mechanism of logical questions (Description Logic Query), which will be supported by the presented ontology. To complete such a system, a tool/method will be created that will derive terminology and inference rules from open data or big data in the SC area, to ensure completeness in terms and inference rules. This tool, of course, can be generalized for other ontologies as well as used for other forms of Natural Language Processing, always in relation to the requirements and results of the research. Undoubtedly, this ontology can be a valuable tool for professionals, researchers, and educators, as it will be able to be extended, modified, and even replaced. Also, research will continue to improve the ontology and explore additional applications, such as machine learning or predictive analytics. The new Supply Chain ontology can be used to improve the performance and coherence of systems in the field of Natural Language Understanding (NLU), Natural Language Generation (NLG,) and Large Language Models (LLM), enhancing understanding and production of natural language through structured representation of terms and relationships between them, categorization and classification of data or feature extraction. Consequently, this ontology can make these models more efficient and applicable in practical situations. In any case, it is certain that the aim of the authors is for the "Multi Solution Ontology" to be a good initial basis for research, study, and practice in every field of Natural Language Processing and always with the perspective of further investigation of possible parameters that will contribute to its improvement.

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Conflict of Interest

The authors have no conflicts of interest to declare.

APPENDIX

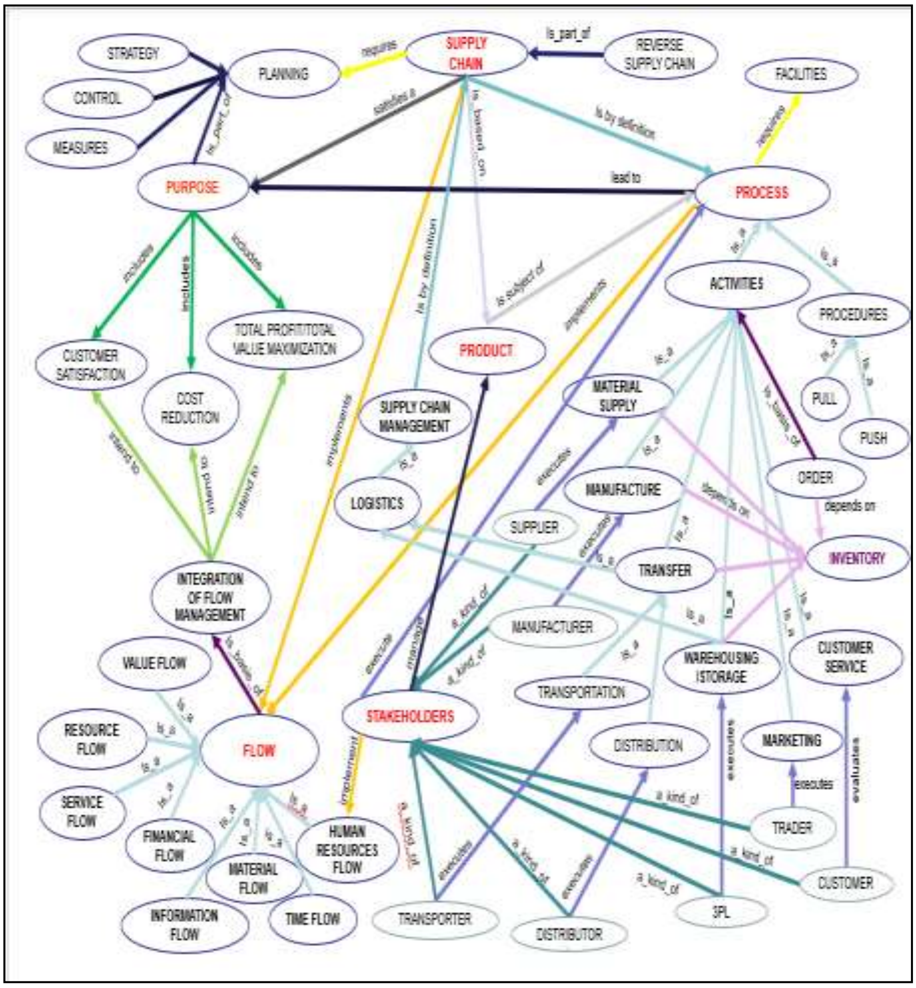

Fig. 1: Snapshot from the SC ontology described in this paper: The main entities (enclosed within elliptical shapes) and the relationships between them (shown by arrows). The different color of the arrows indicates the variety of relationships

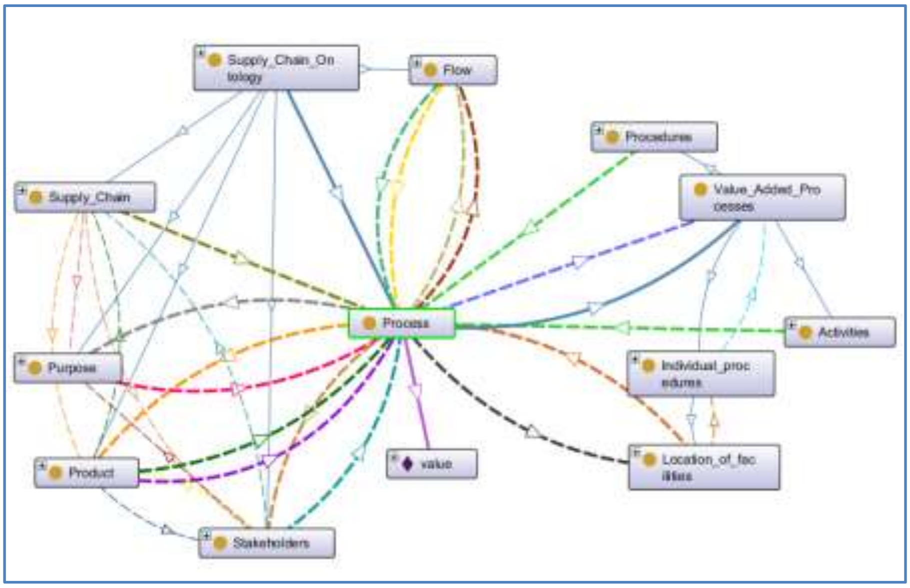

Fig. 2: The relationships of the “Process” entity (at the center of the graph) with the rest of the basic entities (Product, Supply_Chain, Purpose, Flow, Stakeholders), as they are captured in the Protégé (Ontograf) platform

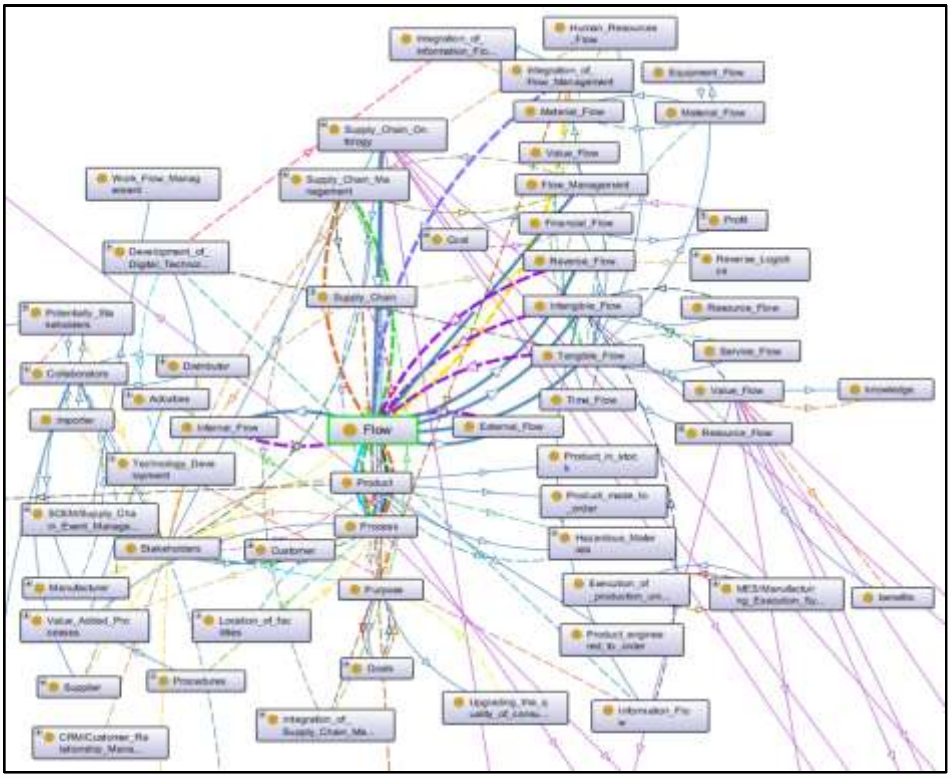

Fig. 3: Screenshot from the Protégé platform showing a sample of the multitude of relationships developed between the six basic entities of the ontology, with the “Flow” entity at the center

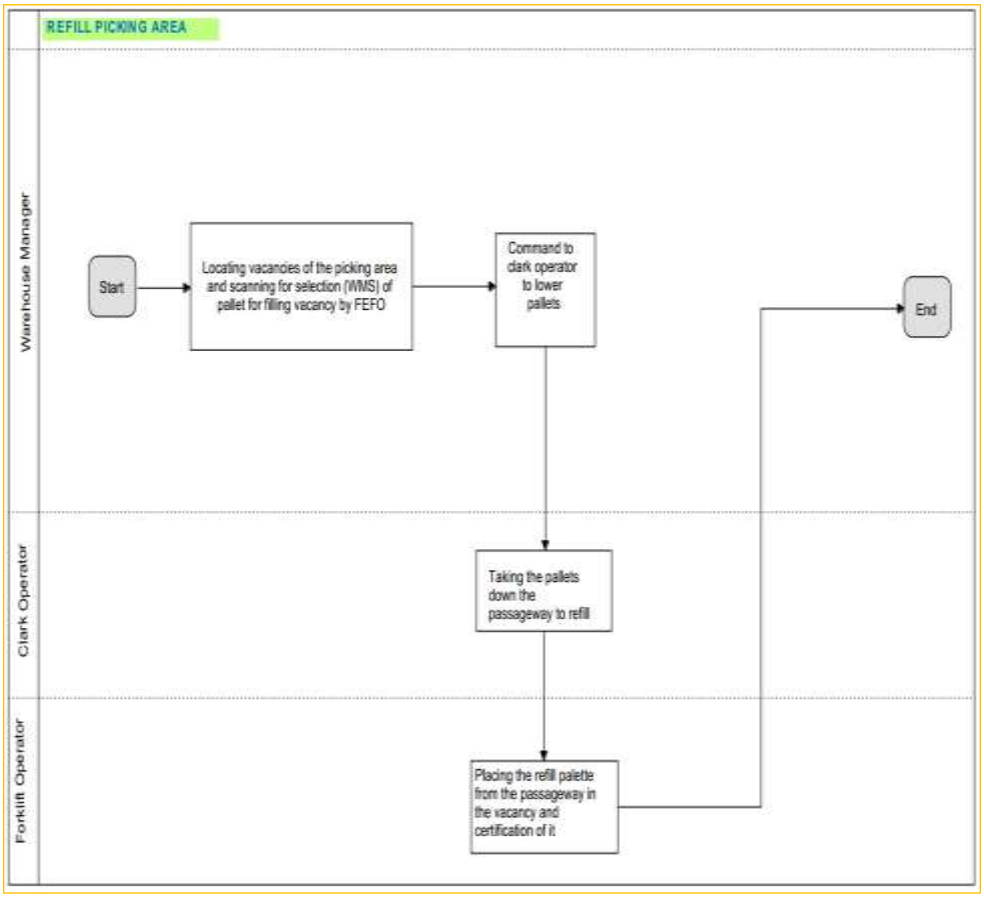

Fig. 4: Diagrammatic representation and interpretation of the "refill picking area" concept in the new ontology of the Supply Chain