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An Enabler for Supplier Discovery in Virtual Supply Chains: A Shared Terminology

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ABSTRACT

Rigid supply-chain organizational structures are giving way to highly dynamic collaborative partnerships. These partnerships will develop rapidly by composing global manufacturing resources in response to open market opportunities; and, they will disband just as rapidly when those opportunities disappear. One critical element of these virtual networks is the *supplier discovery*, i.e., the ability of customers to find suppliers that have the capabilities to meet their requirements. This initial report explores the communication language between the network partners, with particular emphasis on the technical aspects of the transactions.

Keywords

Supply chains, networking, engineering and business objects, business transaction protocols, nomenclatures, product codes, taxonomies, classification systems

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LIST OF ACRONYMS

ANSI	American National Standards Institute
ASC	Accredited Standards Committee
ASME	American Society of Mechanical Engineers
B2B	Business to Business
BOM	Bill of Materials
CAD	Computer Aided Design
CBP	Common Business Process
CICA	Context Inspired Component Architecture
CompTIA	Computing Technology Industry Association
cXML	Commerce Extensible Markup Language
DCOR	Design Chain Operations Reference
DISA	Data Interchange Standards Association
ebXML	Electronic Business Extensible Markup Language
EDI	Electronic Data Interchange
EDIFACT	Electronic Data Interchange for Administration, Commerce, and Transport
EIDX	Electronics Industry Data Exchange Group
EPC	Electronic Product Code
FDA	Food and Drug Administration
GT	Group Technology
GTIN	Global Trade Item Number
HSC	Harmonized System Codes
IEEE	Institute of Electrical & Electronics Engineers
ISDO	International Health Terminology Standards Development Organization
LOOM	Language and environment for constructing intelligent applications
NDC	National Drug Code
OAGIS	Open Applications Group Integration Specification
OEM	Original Equipment Manufacturer
PDM	Product Data Management
PIP	Partner Interface Process
PLM	Product Lifecycle Management
RFI	Request for Information
RFP	Request for proposals
SCC	Supply-Chain Council
SCOR	Supply-Chain Operations Reference
SNOMED	Systematized Nomenclature of Medicine
X12	ANSI ASC electronic data interchange standard
Xcbl	XML Common Business Library
XML	Extensible Markup Language

1 Introduction

1.1 Objective of project

Rigid supply chain structures are giving way to virtual supply networks of collaborative partnerships. These partnerships will develop rapidly in response to market opportunities and they will disband just as quickly when those opportunities disappear. The virtual supply chain will encompass designers, engineers, planners, transporters, suppliers, fabricators, assemblers, buyers, vendors, and service providers, among others.

The project addresses a critical element of these virtual networks, namely, *supplier discovery*, the ability of customers to find suppliers that have the capabilities to meet their requirements. It is expected that this ability will eventually include standard models for representing customer requirements and supplier capabilities, tools that enable customers and suppliers to register those requirements and capabilities, and methods and tools that assist customers to automatically find potential suppliers with matching capabilities. The current planning project will create a technical plan for developing and demonstrating such a network.

1.2 Scope of report

While the overall project addresses the complete supplier discovery phase of the customer-supplier relationship in a virtual network, this initial report explores only one issue: that of the language of communication between the network partners who may have never had any business relationships before.

Furthermore, the report deals only with the technical aspects of the transactions in the virtual supply chain, that is, the technical description of what is sought and the technical description of what is offered. The report does not address any of the business aspects pertaining to cost, price, time to delivery, time/cost tradeoff, volume discounts, counteroffers, etc., nor aspects of business ethics, such as the establishment and maintenance of trust.

On the other hand, while the project is primarily geared towards the manufacturing of products, in this report the design of such products is not excluded. After all, the design document describing a product is as much an artifact as the physical product is. There is no basic difference between a transaction that says "I need a pump (or 100 pumps) manufactured in accordance with the following engineering design description" from one that says "I need a design description of a pump designed in accordance with the following client requirements description" or even one that says "I need an engineering design description of a pump designed in accordance with the following client requirements description and a pump (or 100 pumps) manufactured in accordance to that design description."

1.3 Organization of report

The report is organized as follows: Section 2 presents the preliminary concepts on the notion of engineering objects as compared to business objects. Section 3 presents the initial efforts with a prototype use case followed by a comparison of selected business transaction protocols emphasizing a search for comparable communication efforts.

Section 4 presents the concerns with a literature review on the efforts towards a shared terminology. We conclude with Section 5, presenting a summary of our findings.

2 Preliminary concepts

Srinivasan [1] makes the distinction between *engineering objects*, the information exchanged primarily by the engineering units of enterprises in the design and production of products, and *business objects*, the information exchanged by both engineering and business units of enterprises [1,2]. In the early days of manufacturing information exchange, the two realms could be kept reasonably separate. However, with tighter integration, particularly through Product Data Management (PDM) and even more so through Product Lifecycle Management (PLM), there has emerged an increasing need to bridge the gap between the two realms.

Srinivasan refers to business objects as metadata. In this term he includes both (1) the traditional metadata, defined as "data describing data," which cover such information as author, approver, supplier, version, change history, authorization, effectivity, provenance, etc., and (2) what he calls "aggregate data" such as part number, bill of materials (BOM), product assembly structure, etc. The aggregate data – in particular the part number - provide the link from the business objects to the detailed descriptions that comprise the engineering objects. Quoting from [2]: "these are data *necessary* in communicating about products in contexts other than engineering but which are *sufficient* in themselves for communications without the need for a full, detailed product description. *If the details are needed, as in change management, they can be retrieved via the part number acting as the access key* (italics added for emphasis)." The paper actually defines 4 fields or attributes identifying the part: the part number, a name or brief description, a detailed description and a context identification.

The italicized sentence leads to the crux of the issue addressed in this report. When a firm business relationship exists between client and supplier, the agreed-upon part number fully defines the "language" of communication between the two participants. By extension, the BOM defines a broader "language" consisting of a hierarchy of part numbers. The business relationship needed for such a concise communication "language" may pre-exist through institutional structures or may be established "on the fly" in virtual supply chains after the participants have been identified and the scope of their interaction defined.

The question that this report addresses is: "what language about products is needed in a virtual supply chain before the concise language of part numbers has been mutually agreed upon?"

3 Initial efforts

Initially the project concentrated on three aspects:

- the development of a prototype use case dubbed the "strawman"
- a comparative study of existing business transaction protocols and
- a search for comparable communication efforts.

These three aspects, and a comparison between them, are described below.

3.1 The “strawman” use case

The initial “strawman” use case is patterned after a conceptually similar interaction model developed in a project dealing with healthcare service integration [3].

This use case represents a prototypical situation where a Client engages a Designer to design some product. The Designer in turn engages a Manufacturer to produce the product. For this use case, it is assumed that the product will consist of parts made to order by the Supplier and parts bought from the Warehouse, all to be assembled by the Manufacturer. The Manufacturer eventually delivers the product to the Client, who accepts it.

The Locator is an additional participant that records the identities, locations and capabilities of the other participants – in the present restricted context dealing only with technical aspects; the locator is not a broker that assists in the negotiations.

A transaction is defined as a two-way communication process between two parties. A transaction typically involves the exchange of several messages, such as:

- initial message (query, order, status report, etc.)
- initial acknowledgement
- response
- response acknowledgement.

Error messages, exception reports, etc. are taken to be part of a transaction. Table 1 presents the participants and Table 2 presents the transactions between the participants.

Table 1: Participants in the strawman

Code	Description
S1	Client
S2	Designer
S3	Manufacturer
S4	Locator

Table 2: The transactions between the participants

Code	Description	From participant	To participant	Communication
T1	Designer criteria	Client	Locator	
	Designer alternatives	Locator	Client	
T2	Client-Designer negotiation*	Client	Designer	“Language I” needed
	Designer approval	Client	Locator	
T3	Initial client specs	Client	Designer	
	Design proposal	Designer	Client	
	Design approval*	Client	Designer	Client-designer

				language established
T4	Manufacturer criteria	Designer	Locator	
	Manufacturer alternatives	Locator	Designer	
T5	Manufacturer negotiation*	Designer	Manufacturer	“Language II” needed?
	Manufacturer approval	Designer	Locator	
T6	Manufacturing specifications	Designer	Manufacturer	
	Manufacturer feedback/counterproposal	Manufacturer	Designer	
	Manufacturing approval*	Designer	Manufacturer	Designer-manufacturer language established
T7	Product completion notice	Manufacturer	Designer	
	Product approval*	Designer	Client	
T8	Product delivery	Manufacturer	Client	
	Product acceptance*	Client	Manufacturer	

*may involve multiple iterations

The “Communication” column in Table 2 identifies the transactions that require a communication language to identify the engineering object addressed in the transaction. “Language II” may actually be the part number as described by Srinivasan; however, it is still problematic whether this is the part number assigned by the customer (as, for example, an OEM looking for a supplier of some part) or that assigned by the supplier (as, for example, in shopping from a catalog of available parts).

The transactions are modeled as an information flow diagram in Figure 1 and as an interaction diagram in Figure 2. In the former, transactions are identified by the transaction code in the table above. In the latter, the transactions are categorized as:

- Query/identification of participants
- Contract negotiations leading to participant selection
- Product-centered negotiations moving from requirements to accepted proposal and
- Product-centered negotiations pertaining to the ordering, delivery and acceptance of the product.

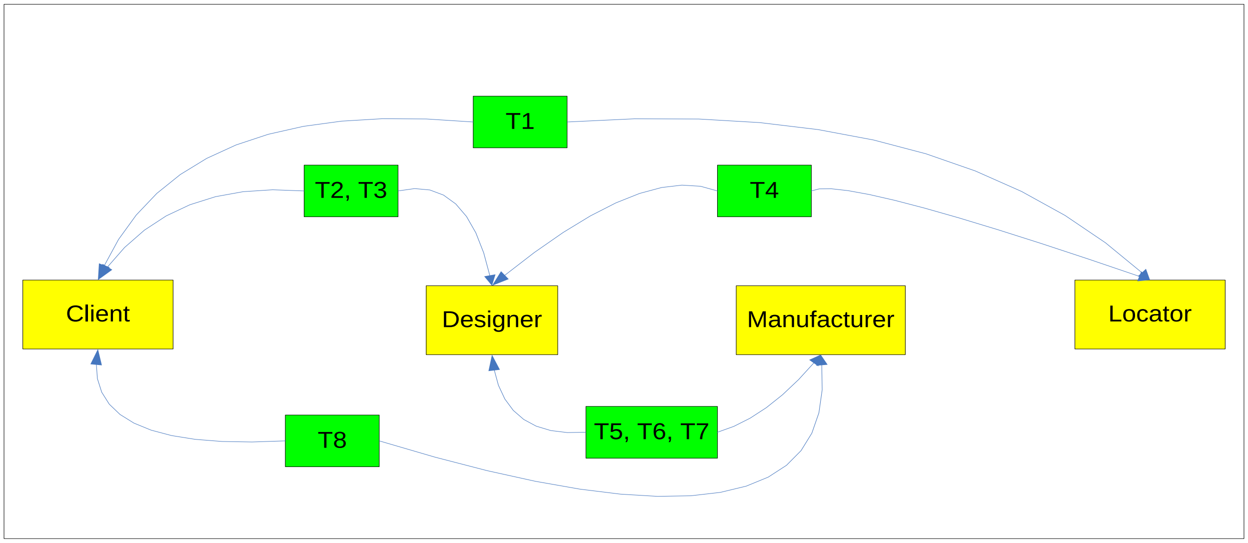

Figure 1: Strawman use case information diagram

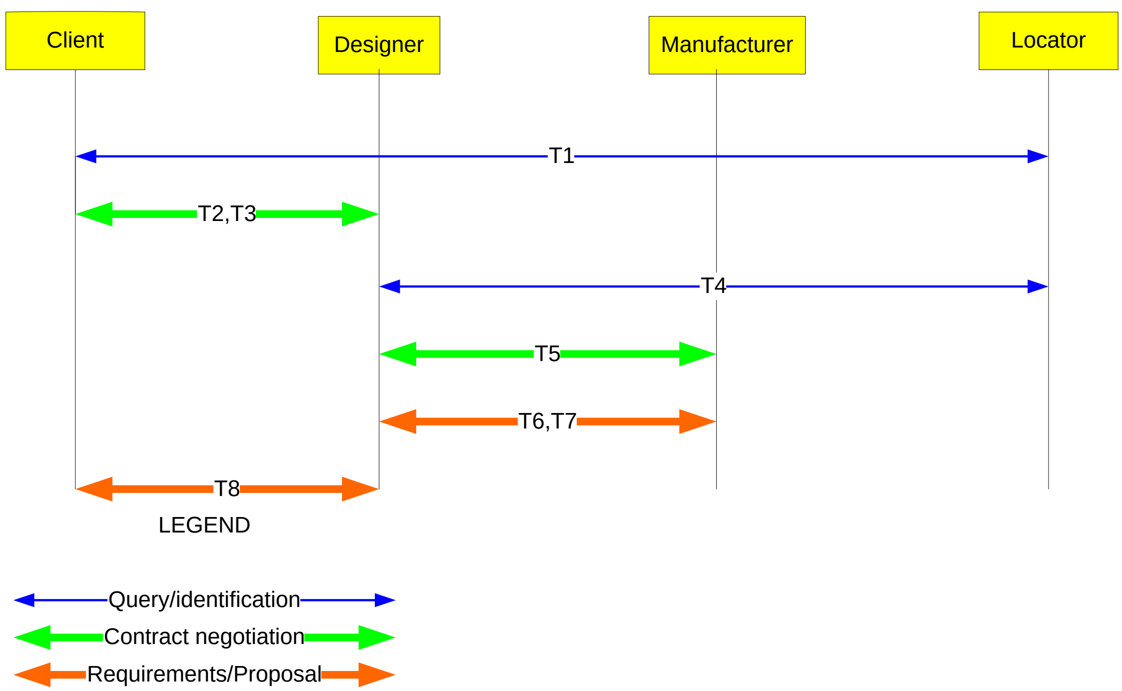

Figure 2: Strawman use case interaction diagram

3.2 Comparative study of business transaction protocols

A number of supply-chain Common Business Processes (CBPs), information standards, messaging standards and reference models have been defined and promulgated by various groups of organizations. Some are industry-specific while others are broader in scope. CBPs are intended to be industry-neutral business processes and re-usable, so that components of a common business process specification can be re-used to create new business processes.

The following business transaction protocols have been reviewed:

ANSI X12 (also known as ANSI ASC X12) is the U.S. national standards body for the development and maintenance of Electronic Data Interchange (EDI) standards. X12 has an underlying syntax, which is an ANSI standard. Within that syntax, there are directories of data elements, composite data elements, segments, and messages. There are conventions for placing messages in an "envelope", which identifies the sender and receiver and other attributes of a transmission [4].

EDIFACT (Electronic Data Interchange for Administration, Commerce, and Transport) is the international Electronic Data Interchange developed under the United Nations. EDIFACT has an underlying syntax, which is an ISO standard. Within that syntax, there are directories of data elements, composite data elements, segments, and messages [5].

EIDX represents the Electronics Industry Data Exchange Group. As part of the Computing Technology Industry Association (CompTIA), EIDX provides a unified voice, global leadership and strategic direction to further e-business interoperability. EIDX is committed to advancing industry growth through the development of standards, best practices, accreditations, professional education and development, tools and business solutions [6].

RosettaNet is an independent, self-funded, non-profit consortium dedicated to the development and deployment of standard electronic business interfaces. These standards form a common e-Business language, aligning processes between supply chain partners on a global basis. RosettaNet's Partner Interface Processes (PIP) allow trading partners of all sizes to connect electronically to process transactions and move information within their extended supply chains [7].

OAGIS (Open Applications Group Integration Specification) is an effort to provide a canonical business language for information integration. OAGIS uses XML as the common alphabet for defining business messages and for identifying business processes (scenarios) that allow businesses and business applications to communicate. OAGIS accommodates the additional requirements of specific industries by partnering with various vertical industry groups [8].

SCOR (Supply-Chain Operations Reference) is not a business transaction protocol per se but a process reference model developed by the Supply-Chain Council (SCC) [9]. The SCC is an independent, not-for-profit, global corporation with membership open to all companies and organizations interested in applying and advancing the state-of-the-art in supply and design chain management systems and practices. SCOR has been adopted as the cross-industry de facto standard diagnostic tool for supply chain management. It is a hierarchical model that has five major building-block processes: plan, make, source, deliver, and return [10].

DCOR (Design Chain Operations Reference) captures the SCC's view of design chain management [11]. The structure is based on the same hierarchical philosophy as SCOR, but with five different building-block processes: plan, research, design, integrate, and amend.

Other business transaction protocols that have not been reviewed include: B2B, cXML, Xcbl, E-business, Enterprise application integration, Standard Carrier Alpha Codes, DISA, CICA, ebXML, among others.

3.3 Comparisons

Comparison of the "strawman" use case and the protocols examined shows that essentially all "strawman" messages and transactions have equivalents in all of the protocols reviewed. On the other hand, where these protocols support alternate transactions, the "strawman" transactions invariably map onto the simplest, most basic variant of the transactions supported by each of the protocols.
In general most of "business processes" as depicted in the above protocols, tend to be coarser-grained than the "strawman" transactions. However, several protocols present detailed diagrams describing each business process in terms of their individual process steps. The detailed interaction diagrams identify the business documents exchanged between the participants; these correspond directly to the "strawman" messages. In comparison to the above protocols, the "strawman" model is highly simplified. Essentially the protocols depict a global model that recognizes and implements:

- many more business processes
- several variants (models) of a "generic" business process
- additional/optional steps within one business process variant and
- several implementation options.

More importantly, the existing protocols support only the lowest level of customer-supplier interaction, which may be termed the "commodity" level. Even though the transaction protocols were developed and are promulgated by organizations dealing with technical products, the transactions supported by the protocols could just as well apply to sacks of soybeans as to pumps or airplanes (in fairness, it is to be pointed out that the transactions of the "strawman" use case do not contain any technical information either). Using the distinction introduced in Section 2, the transactions deal entirely with *business objects* and contain no information about engineering objects except as they are abstracted into a single item number or designation. What appears to be totally absent in the protocols examined is any reference to the *engineering objects* that underlie many of the transactions. This is particularly noticeable in the case in EIDX, which is specifically devoted to electronics industry data exchange. It appears that the dichotomy between engineering objects and business objects discussed by Srinivasan [2] is complete.
A very preliminary list of transactions between clients and suppliers that involve both business and technical objects is shown below. Typical examples are shown for each transaction class.

- Client's inquiry about potential supplier's capabilities and the supplier's response
    - E.g., supplier's technical capabilities, backlog, regulations in place, standards in use, product data transmission standards available

- Potential supplier's Request for Information (RFI) to client regarding the Request for Proposal (RFP) issued prior to contract award and the client's response
    - E.g., desired product tolerances, options, finishes and colors.

- Potential supplier's counterproposal to the RFP and the client's response
    - E.g., RFP calls for bolts, supplier offers discount on subassemblies of bolts, nuts and washers.
    - E.g., RFP calls for forming and welding, supplier only offers forming.

- Supplier's RFI to client regarding the contract in effect and the client's response
    - E.g., product tolerances, options, finishes, colors not fully specified in the contract.
    - E.g., request for clarification of CAD or other product data provided in contract.

- Supplier's request for approval of substitutions and the client's response
    - E.g., request to substitute materials and curing or finishing processes.

- Supplier's submission of alternatives within the contract and the client's response
    - E.g., submission requesting approval of alternate materials and curing or finishing processes.

- Supplier's submission of intermediate process documents, test data or product samples for client action or approval and client's response
    - E.g., submission of detailed "shop drawings" for review and approval before fabrication can begin.

- Change orders from the client and the supplier's response
    - E.g., order to extend, condense or otherwise modify contract for product.

- Client's decision concerning acceptance or rejection of delivered products and supplier's response
    - E.g., client's "punch list" of corrective steps the supplier needs to take before product is accepted.
    - E.g., client's "rejection slip" listing reasons for the rejection of the product sent by the supplier.

Admittedly, many of the transactions illustrated above will occur in such a late phase of the process that agreement in item numbers will already have been established. However, the first transaction illustrated above will take place in the supplier discovery phase, before such agreement is reached.

3.4 Process information sharing

A side investigation was carried out to ascertain the degree to which process information may be shared between customer and supplier.

One effort, the proposed ASME standard “B5/TC56: Information Technology for Machine Tools” for a “virtual machine tool,” intends to develop “a model that predicts an output of the machining process by simulating the actions of the machine tool in response to the part program and the environment” [12]. The intended setting is that of a manufacturer wishing to simulate a particular machine tool before buying it.
The presentation describing the committee’s work states that:
“The critical enabler is efficient access to relevant data:

- The part (geometry, tolerances, material)
- The process plan (part program, set-up and fixturing)
- The machine tool(s)
- The tool(s)
- The machine environment.”

For the current project, only the first class of data is relevant, that is, *what* is to be supplied. The second class, *how* it is to be made, has traditionally been the province of the supplier. In fact, it can be argued that *a priori* process plan that is not based on a particular supplier’s available manufacturing resources is bound to be sub-optimal, as it cannot exploit the supplier’s competitive advantages. Furthermore, the description above, “part (geometry, tolerances, material),” clearly calls for the fully elaborated *engineering object.* The work on a virtual machine is therefore not relevant to the communication issue in the virtual supply chain.

In a similar vein, Mahesh [13] and Serm [14] describe tightly integrated design, engineering, manufacturing and logistics systems where process as well as product information is shared between participants geographically distributed around the world interacting via autonomous software agents [13,14]. From the project’s standpoint, both systems require more manufacturing and logistics process knowledge on the part of the customer than can be assumed to exist in a typical customer-supplier transaction.

4 Towards a shared terminology

The key concern in effecting the supplier discovery phase of the proposed virtual supply chain is an agreement between customer and (potential) supplier on *what* is to be supplied. This concern leads to a search for a computer-processable terminology common to the customer and supplier. Possible ways of addressing this concern are described below. A literature search for alternative shared terminologies provides examples of three approaches to be described below.

4.1 Standard nomenclatures

Standard nomenclatures provide a means for interested parties to communicate through terms agreed upon by the parties involved. There are literally hundreds such standard nomenclatures. One example is the ANSI/IEEE 505-1977 standard nomenclature for generating station electric power systems [15]. An excerpt taken directly from another standard nomenclature, ANSI A250.7-1997 Nomenclature for Standard Steel Doors and Frames [16] is shown below:

“[**ADJUSTABLE BASE ANCHOR**]
a device used to anchor frames to a depressed slab or below finished floor line
[**ADJUSTABLE FRAME**]
frame with profile in two or more pieces that will adjust to accommodate several wall thickness—also known as expandable frame
[**ANCHOR**]
a device for attaching frame to the surrounding structure
[**APPLIED STOP**]
surface mounted stop attached to a cased opening
[**APPLIED TRIM**]
decorative piece applied onto the face of a frame”

It can be seen that such standard nomenclatures are designed for human comprehension and communication and are not computer-processable. Furthermore, they are linear lists with no indications of hierarchical relationships between terms. As such, they are of little value to the shared vocabularies that we seek.

4.2 Product codes

Product codes encode product identification into a numeric code. Two examples follow:

HSC (Harmonized System Codes) is a commonly used set of product codes for classifying products for trading purposes. This classification is used by customs officials around the world to determine the duties, taxes and regulations that apply to the product. Under HSC, products are assigned a six-digit identifying number:

- The first two digits of this number identify the chapter into which the product falls, as follows:

  01-05 Animal & Animal Products
  …
  84-85 Machinery / Electrical
  …
  98-99 Service

  .
- The second two digits identify the heading within that chapter. As an example, the segment of chapter 84 yields:

  8459 machine tools for drilling, boring, milling, etc.
  8460 machine tools for honing or finishing metal, etc.
  8461 machine tools for shaping, slotting, gear cut, etc.
  …
  8465 machine tools for working wood, cork, bone, etc.
  8466 parts, etc for machine tools of head 8459 to 8465.

- The final two digits identify a specific class of products. As an example, heading 8461 contains:

846110 Planing Machines
846120 Shaping or Slotting Machines
846130 Broaching Machines
846140 Gear Cutting, Gear Grinding or Gear Finishing Machines
846150 Sewing or Cutting-off Machines
846190 Other Machine-tools Working by Removing Metal

Each country may further expand HSC by adding additional digits. The U. S. version of the Harmonized System is maintained by the U.S. Department of Commerce Census Bureau Foreign Trade Division [17].

It can be seen that the HSC codes have insufficient precision for identifying products to the depth that virtual supply chains would demand. Furthermore, there is no mechanism for customization.

NDC (National Drug Code) [18] is another well-known product code. It is an 11-digit, 3-segment number assigned to each medication listed under Section 510 of the U.S. Food, Drug, and Cosmetic Act. The number identifies the labeler or vendor, product, and trade package size, as follows:

- The first segment, the labeler code, is assigned by the Food and Drug Administration (FDA). A labeler is any firm that manufactures, repacks or distributes a drug product.
- The second segment, the product code, identifies a specific strength, dosage form, and formulation for a particular firm.
- The third segment, the package code. identifies package sizes.

Again, as in HSC there are no provisions for customization.

GS1 is a system of standards that governs the bar codes ubiquitous in supply chain commerce [19]. The GS1 Identification System provides two types of identifiers. The first or primary identifiers are called the Global Trade Item Number (GTIN) or Global Location Number (GLN). Other GS1 keys identify trade items (GTIN), locations/trading parties i.e., GLN, logistic units i.e., Serial Shipping Container Code (SSCC), individual assets i.e., Global Individual Asset Identifier (GIAI), returnable assets i.e., The Global Returnable Asset Identifier (GRAI), service relationships (GSRN), and document types i.e., Global Document Type Identifier (GDTI). The GS1 Identification System also provides key "attributes" such as Lot Numbers or Expiration Date.

Companies joining the system obtain a GS1 Company Prefix from a GS1 Member Organization and then assign reference identification numbers to their trade items (products or services), themselves (as a legal entity), locations, logistic units, individual company assets, returnable assets (returnable pallets, kegs, tubs), and service relationships. Finally, they generate numbers for the bar codes using the GS1 Company Prefix in combination with the assigned reference numbers.

It appears that all customization takes place only at the company level, so that the GTIN assigned by the supplier is essentially equivalent to the item number, but it is arrived at unilaterally by the supplier without the customer's input. Furthermore, the GS1 system appears to be only a standard for syntax, with no global contents or semantics.

EPC (Electronic Product Code) proposes a new object identification scheme which uniquely identifies objects and facilitates tracking throughout the product life cycle [20]. The EPC is a short, simple and extensible code designed for efficient referencing to networked information. It is intended that a unique EPC be assigned to one and only one physical item. For this reason alone, the EPC is not relevant to the subject at hand, the discovery of potential suppliers for a product that may not have been designed or manufactured yet.

4.3 Taxonomies

Taxonomies are composed of taxonomic units that are typically arranged in a hierarchical structure and are related by parent-child relationships. The term taxonomy may also apply to relationship schemes other than parent-child hierarchies, such as network structures with other types of relationships.

Electromechanical Component Taxonomy is presented in the Appendix of [21]. The levels of the taxonomy are:

- Primary component classification (branchers, channelers, etc.)
- Secondary component classification (separators and distributors as subsets of branchers)
- Component term (divider, vibrator, material filter, etc. as subsets of separators)
- Component subset (permeable membrane, rake and screen as subsets of material filter).

In addition, synonyms and definitions of the leaf nodes are provided. As many of the taxonomies surveyed, this one was developed for the support of knowledge- and function-based conceptual design.

Another conceptual design paper refers to catalogs of standard components but does not elaborate the catalog's structure or content [22].

Active Catalog is a third taxonomy developed for the support of conceptual design [23]. Quoting: "An Active Catalog, as the name suggests, is a catalog containing active, i.e., behavioral and dynamic, information of design components and parts described by a rich set of models of different modalities to facilitate information consumption. The modalities of models include, for example, a mathematical model, simulation model, engineering drawing, 3D geometrical model, electronic model, textural and semantic description, a set of information viewers and even simulation code. The major components or substrates of an Active Catalog are a semantic model of a domain, a set of models in the above mentioned modalities, a set of databases that stores the models, a search engine that recognizes users' queries specified in a vocabulary given by the semantic model of the domain, and a set of helper applications for viewing the corresponding types of models."

The application demonstrated deals with pumps. "The pump taxonomy is organized as a graph rather than a tree structure by taking advantage of LOOM's multiple inheritance. This provides multiple paths to a specific pump type. At the top levels of the taxonomy are a few abstract type-definitions for pumps, such as Kinetic Pumps and Positive Displacement Pumps, with Special Pumps, Peripheral Pumps and Centrifugal Pumps being subclasses of Kinetic Pumps, and Rotary Pumps, Blow Case Pumps, and Reciprocating Pumps being subclasses of Positive Displacement Pumps. In the middle levels are a rich set of abstract classes defining varieties of pump classes. At the bottom levels a large number of pump classes are defined by combining types from top and middle levels. For example, Reciprocating Single Acting Power Multiplex Pumps are defined as sub-class of Reciprocating Pumps, Single Acting Power Pumps, and Multiplex Pumps."

4.4 Faceted classification systems

A faceted classification system provides for multiple classifications of an object, enabling the classifications to be ordered in multiple ways, rather than in a single, pre-determined, taxonomic order. A facet comprises "clearly defined, mutually exclusive, and collectively exhaustive aspects, properties or characteristics of a class or specific subject" [24].

SNOMED (Systematized Nomenclature of Medicine) is a well-known faceted classification system of medical knowledge. SNOMED uses 11 classification axes to classify each disease. The axes are:

- T (Topography) -- Anatomic terms
- M (Morphology) -- Changes found in cells, tissues and organs
- L (Living organisms) -- Bacteria and viruses
- C (Chemical) -- Drugs
- F (Function) -- Signs and symptoms
- J (Occupation) -- Terms that describe the occupation
- D (Diagnosis) -- Diagnostic terms
- P (Procedure) -- Administrative, diagnostic and therapeutic procedures
- A (Physical agents, forces, activities) -- Devices and activities associated with the disease
- S (Social context) -- Social conditions and important relationships in medicine
- G (General) -- Syntactic linkages and qualifiers

For example, a disease may be located in a body organ which results in a code in a topography axis and may lead to morphological alterations represented by a morphology code.

4.5 Group Technology

Group Technology (GT) is an approach that seeks to identify attributes of a population that permit its members to be collected into groups, also called families. In an industry, usually similar parts are identified and grouped together to take advantage of their similarities in design and manufacturing. Contemporary GT methods apply coding schemes as a popular method for capturing the design and manufacturing information pertinent to the parts to be grouped. A GT code is an alphanumeric string, which represents critical information about a product in a concise manner. Conventional GT coding and classification schemes attempt to capture design and manufacturing attributes such as the main shape, size, feature of the product, production quantity and the material [26]. Coding schemes for parts classification either fall into a hierarchical structure, chain-type structure or a hybrid of the two structures [27]. For example the Opitz coding system uses the following digit sequence:

12345 6789 ABCD

The basic code consists of nine digits, which can be extended by adding four more characters. The first nine digits are intended to convey both design and manufacturing data. 12345, are called the “form code” and describe the primary attributes of the part. The next four digits, 6789, constitute the “supplementary code” which indicate attributes useful to manufacturing. The extra four characters, ABCD, are referred to as the “secondary code” and intended to identify the production operation type and sequence.

GT codes can be effectively used in database searches to retrieve close matches to a given design and generate new process plans automatically using a knowledge-based system and to access manufacturability of a product design. But, with a gamut of available coding systems for the classification, none has been universally adopted.

5 Summary of findings

a) There is no comprehensive description of process plans for manufacturing all products. However, such a description is not an absolute necessity for an initial version of the virtual supply network. The network can come into existence by using the traditional division of knowledge where process plan knowledge resides exclusively with the supplier. Therefore, the network should rely on product description alone, leaving it up to the supplier to devise a manufacturing process as part of the supplier’s response to an inquiry, RFP or purchase order.

b) It appears from the literature surveyed that a comprehensive taxonomy of all products that may be directly used in supply chain transactions does not exist. In fact, it is clear that such an exhaustive list is simply not feasible; among other reasons, in today’s rapidly changing technology any static list would quickly become outdated. A prototype version of the virtual supply network could be launched in a restricted domain where the shared vocabulary could be built up interactively by the participants. Initially, the Locator introduced in the "strawman" use case could maintain the vocabulary and update it as needed.

c) For a broader domain, a shared nomenclature is still needed. The approaches to shared descriptions reviewed here may serve as guidelines.

d) The most promising approach would be the development of a multifaceted classification system for manufactured electro-mechanical products that could eventually serve as the basis of a standard. The structure of the system could be patterned after that of SNOMED, but it will first require a major cooperative effort to decide on a comprehensive set of classification axes that "span" the domain of discourse. One axis would certainly be "Function" and it could initially be based on the taxonomy presented by Porter and Stone [21]. Further axes may relate to "Material" and "Manufacturing process," but it should be possible to access product descriptions without classifiers along these axes. Other possible axes may refer to the "Environment" or "Context" in which the product is used and "Safety" issues associated with the product.

The implementation of the classification system would have to respond to the rapidly changing nature of the global manufacturing enterprise. Modifications, particularly additions, would have to be done rapidly, without committee deliberations and multiple levels of ballots. Dynamic models, such as open source software, open standards and Wikipedia, will have to be investigated. Eventually, an organization would have to be formed to manage and maintain the system, similar to what ISDO (International Health Terminology Standards Development Organization) does for SNOMED [25].

DISCLAIMER

No approval or endorsement of any commercial product by the National Institute of Standards and Technology is intended or implied.

6 References

1. Srinivasan, V., Lammer, L., Vettermann, S., On Architecting and Implementing a Product Information Sharing Service, Journal of Computing and Information Science in Engineering, Vol. 8, 2008, pp. 6-17.
2. Srinivasan, V., An Integration Framework for Product Lifecycle Management, Computer-Aided Design, 2008, doi:10.1016/j.cad.2008.12.001
3. Fenves, S., Subrahmanian, E., Goyal, P., Angbo, J., Daoud, F., Sriram, R.D., The Architecture Development Facilitator (ADF) First Year Report, NIST Interagency/Internal Report (NISTIR) - 7411, 2007.
4. http://www.x12.org/, Accessed March 31, 2009.
5. http://www.stylusstudio.com/edifact/, Accessed 11 March 31, 2009.

6. http://eidx.comptia.org/, Accessed March 31, 2009.
7. http://www.rosettanet.org/, Accessed March 31, 2009.
8. http://www.openapplications.org/, Accessed 11 March 31, 2009.
9. http://www.supply-chain.org/, Accessed March 31, 2009.
10. http://www.supply-chain.org/cs/root/scor_tools_resources/scor_model/scor_model/, Accessed March 31, 2009.
11. http://www.supply-chain.org/cs/root/scor_tools_resources/designchain_dcor/dcor_models/, Accessed March 31, 2009.
12. ASME B5/TC56 Committee, Information Technology for Machine Tools, ASME B5.59-1 (2005), Data specification for machine tool performance tests, ASME, New York.
13. Mahesh, M., Ong, S.K., Nee, A.Y.C., Fuh, J.Y.H., Zhang, Y.F., Towards A Generic Distributed and Collaborative Digital Manufacturing, Robotics and Computer Integrated Manufacturing (RCIM), Vol. 23, No 3, 2007, pp 267-275.
14. Boonserm, K., Ivezic, N., Wysk, R.A., Jones, A., Integrated Product and Process Data for Business to Business Collaboration, Artificial Intelligence for Engineering Design, Analysis, and Manufacturing (AIEDAM), Vol. 17, No. 3, 2003, pp 253-270.
15. IEEE Standard, Nomenclature for Generating Station Electric Power Systems, ANSI/1EEE Std 505-1977, http://ieeexplore.ieee.org/Xplore/login.jsp?url=/iel1/2660/850/00021012.pdf?arnumber=21012, Accessed March 31, 2009.
16. ANSI A250.7-1997, American National Standard Nomenclature for Standard Steel Doors and Steel Frames, http://www.deansteelmarine.com/__files/A250_7%20Better%20Nomeclature.pdf, Accessed March 31, 2009.
17. http://www.census.gov/foreign-trade/reference/codes/index.html, Accessed 11 March 31, 2009.
18. http://www.fda.gov/cder/ndc/, Accessed March 31, 2009.
19. http://gpcbrowser.gs1.org/Default.aspx, Accessed March 31, 2009.
20. Brock, D.L., The Electronic Product Code (EPC): A Naming Scheme for Physical Objects Biography, http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.61.6514/, Accessed March 31, 2009.
21. Kurtoglu, T., A Computational Approach to Innovative Conceptual Design, Dissertation, University of Texas, August 2007.
22. Vargas-Hernandez, N., Shah, J.J., Lacroix, Z., Development of a Computer Aided Conceptual Design Tool for Complex Electromechanical Systems, AAAI Technical Report SS-03-02, 2003, http://www.aaai.org/Library/Symposia/Spring/2003/ss03-02-035.php/, Accessed March 31, 2009.
23. Coutinho, M., Eleish, R., Kim, J., Kumar, V., Ling, S. R., Active Catalogs: Integrated Support for Component Engineering, Proceedings of the American Society of Mechanical Engineers, 18th Computers in Engineering Conference, 1998. http://www.isi.edu/~jihie/asme-98.ps/, Accessed March 31, 2009.

24. Taylor, A. G., Introduction to Cataloging and Classification, 8th edition, Libraries Unlimited, Englewood, CO, 1992.
25. http://www.ihtsdo.org/, Accessed 11 March 31, 2009.
26. Groover, M.P, Automation, production systems, and computer-integrated manufacturing, 3rd edition, Prentice Hall, New York NY, 2007.
27. Anupam, G., Expansion of Group Technology Part Coding Based on Functionality, MS Thesis, University of Cincinnati, Industrial Engineering Department, 2001.