Knowledge Management in the Virtual Enterprise: Web Based Systems for Electronic Manufacturing

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Abstract This chapter discusses the typical characteristics of virtual enterprises. Additionally, web based systems features are analysed. The focus is on modeling and implementation of such systems with respect to handling the knowledge in the virtual enterprise. Typical applications that have been developed to support the knowledge management in the virtual enterprise are discussed. Especially, the support of business process execution as the core of a knowledge management approach is discussed. Use of modern technologies for business process modeling like the UML is discussed. Flexible data exchange standards are compared like the XML to other alternatives and the advantages are demonstrated in a series of industrial scenarios. Finally, the synthesis of these technologies to implement web based systems is discussed.

Keywords: Virtual enterprise; Knowledge management; Business process modeling; Data exchange.

1 Introduction

Virtual enterprises (VE) are conglomerates of regular enterprises that collaborate on an ad hoc basis to carry out an inter-organisational business process. The virtual enterprise has a dynamic structure that depends on the particular process that needs to be carried out. Enterprises can join or leave the virtual enterprise at short notice, depending on the capacity and the opportunity. A virtual corporation gathers data on markets and customer needs, combines it with the newest design methods and computer-integrated production processes and operates as an integrated network that includes also suppliers, distributors, retailers and consumers. It looks edgeless to the outside observer, with permeable and continuously changing interfaces between company, supplier, and customer. And also inside, the view will be

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amorphous with operating divisions constantly reforming according to need. On the one hand, member enterprises (MEs) in a virtual enterprise will keep their independence and autonomy however they will contribute their core competencies to the virtual enterprise. Through the combination of the core competencies of member enterprises, the virtual enterprise may become a best-of-everything enterprise. Nowadays, the virtual enterprise is considered as one of the most promising paradigms for the future enterprises [11]. A VE, is an ad hoc organisation that joins core competencies and commits its resources to respond to unexpected business opportunities, such as the one-time production of a specific landing gear in the case of some unexpected airplane damage, a batch of mobile phones as part of some promotional activity, or some emerging niche market [1]. An example of this kind of virtual enterprise include the maritime industry where a number of partners join their efforts to accomplish the repair of a ship while for another ship a different set of partners would collaborate with the shipyard depending on the particular repair that a ship may require. For today's firms, IT infrastructure capabilities underpin the emergence of the virtual corporation [1].

The virtual enterprise integration can be hierarchically classified into three levels [11]:

- Physical system integration realizes communication among physical components distributed at various member enterprises by means of computer networks and communication protocols. It addresses system interconnection and data exchange both within individual enterprises and among multiple enterprises. It can also be called integration at the datum level.
- Application integration realizes interoperability and information sharing among computerized applications distributed at various member enterprises. It provides interoperability of applications on heterogeneous platforms as well as access to common shared data by distributed applications. It can also be called integration at the information level.
- Business integration realizes business process coordination and knowledge sharing among functional entities distributed at various member enterprises. It provides protocols and/or mechanisms to enable functional entities to collaboratively execute the whole business process of the virtual enterprise. It can also be called integration at the knowledge level.

Economic pressures such as margin erosion, development costs and time-based competition, are placing emphasis on how organizations operate and interoperate with other enterprises to achieve a common business goal. Business-to-Business (B2B) interactions must simply take place, and organizations must work more directly with their suppliers and customers to respond more quickly to changes. At the same time, rapid growth of web technologies is beginning to transform traditional inter-enterprise business models and allows virtual enterprise creation. To enable organizations to adapt to this new business environment, middleware is required for providing dynamic and flexible integration between partners in the value chain. Although new technologies are needed to enable such integration, they have to work seamlessly with both intra-enterprise and inter-enterprise business processes, while maintaining the privacy of information and the autonomy of participants [16]. The following discussion elaborates concepts that are developed to facilitate the knowledge management in the virtual enterprise, utilizing emergent information technologies such as the web services, agent based systems, data exchange technologies including as the eXtensible Markup Language (XML) and others.

2 Characteristics of the Virtual Enterprise

Virtual enterprises are becoming a major trend in cooperative industry. This is not only expressed in a rising number of established co-operations, but also by the development of various new kinds of entrepreneurial co-operation such as Value-Added Partnerships, Strategic Alliances, Strategic Networks and Virtual Enterprises [15]. Different enterprises coordinate the necessary means to accomplish shared activities or reach common goals.

One of the most striking characteristics of the VE is its opportunistic nature. Enterprises may use the VE strategy to meet unexpected change and unforeseen events and this way become agile. One of the beneficial results is that unused capacities or planned overcapacity can be made productive. To cope with the momentary unavailability of a particular type of capability, a VE will include several members with similar capabilities (redundancy). This is opposed to the concept of lean structure, but it will help the VE itself to achieve agility [1].

These characteristics distinguish the VE from a more long-term inter-organisational structure, such as the supply chain or the extended enterprise.

A supply chain is a stable set of business activities by which several enterprises have agreed to contribute their expertise towards the completion and supply of a product that caters to a relatively stable market. Communications among the supply chain partners have been designed mainly to minimise inventory and lead times across the whole chain. The Information and Computer Technology (ICT) integration in a supply chain is based on Electronic Data Interchange (EDI)-like information flow [23] as an integral part of the operational process, and also involves the exchange of product data, forecasts and production schedules. In the supply chain, capacities are committed for a longer period of time, and the high level of ICT integration is needed to provide the necessary performance in terms of lead time, minimisation of inventory, and customer-order driven product diversity [11].

The extended enterprise can be regarded as a kind of Virtual Corporation that has evolved from the supply chain. As the supply chain grows into a multi-tiered enterprise with systems suppliers at multiple tiers, the scope of the collaboration will reach beyond production into the design, development and costing. The extended enterprise is typical for complex products with large to medium lot sizes, and considerable customer driven product differentiation. The level of integration in an extended enterprise is tight, allowing a high level of synchronisation of the process development, production and delivery schedules of the collaborating partners [11]. Virtual enterprise is one manifestation of organizational response to the dynamic and globalization of today's markets. The baseline for a virtual enterprise is the customer needs. These needs can be extensive and unique (e. g. a large project based contract) or small but with numerous variations [11]. For example a number of complementary companies specializing in the repair and maintenance of a ship may form a virtual enterprise to give a comprehensive service to its potential customers, namely the shipowners. These services might include the maintenance of hull structure, all forms of energy supplies, telecommunication links, repair/maintenance of plate structures, engine elements, ventilation equipment, certification of repairs, tagging services etc. A typical shiprepair job involves a large number of partners, with the shipyard being the main one.

The activities required for the completion of a repair job, set the boundaries of a typical project shop [4]. The other participating partners, performing activities that are critical to the overall shiprepair operation, are comprised of [5, 6, 7]:

- The material suppliers that supply material to the shipyard.
- The service suppliers that are called subcontractors, providing labour to the shipyard; these companies, offer specialized personnel, capable of carrying out part of the shiprepair activities in case the shipyard does not have such expertise or the capacity, required for the completion of a shiprepair contract.
- The shipowner is the customer that brings the ship for repair.

Each of these services will require unique core competencies. Thus, several small specialist companies can increase their potential customer base by pooling their competencies. The attractiveness for the customer of such an enterprise will be that there will be only a single contact point for most of the shiprepair related problems. This is identifiable in the UML use case model [2] of the shiprepair process; a ship owner interacts only with the contact partner that is the shipyard, the shipyard in its own turn cooperates with numerous companies represented here by the role of the Subcontractor [7] as in Fig 1.

The use case diagram illustrates the actions of the major actors in a shiprepair scenario including planning in a shipyard, planning in a subcontractor, estimating production workload to be planned, etc. Alternative models of the same scenario can be built, depending on the necessary level of detail.

Jagdev and Thoben conclude that a virtual enterprise can be defined as a network of independent organizations that jointly form an entity committed to provide a product or service. From the customer's perspective, as far as that product/service is concerned, these independent organisations for all practical and operational purposes, are virtually acting as a single entity/enterprise. Taken from this perspective, the following are the major characteristics of the virtual enterprise [1]:

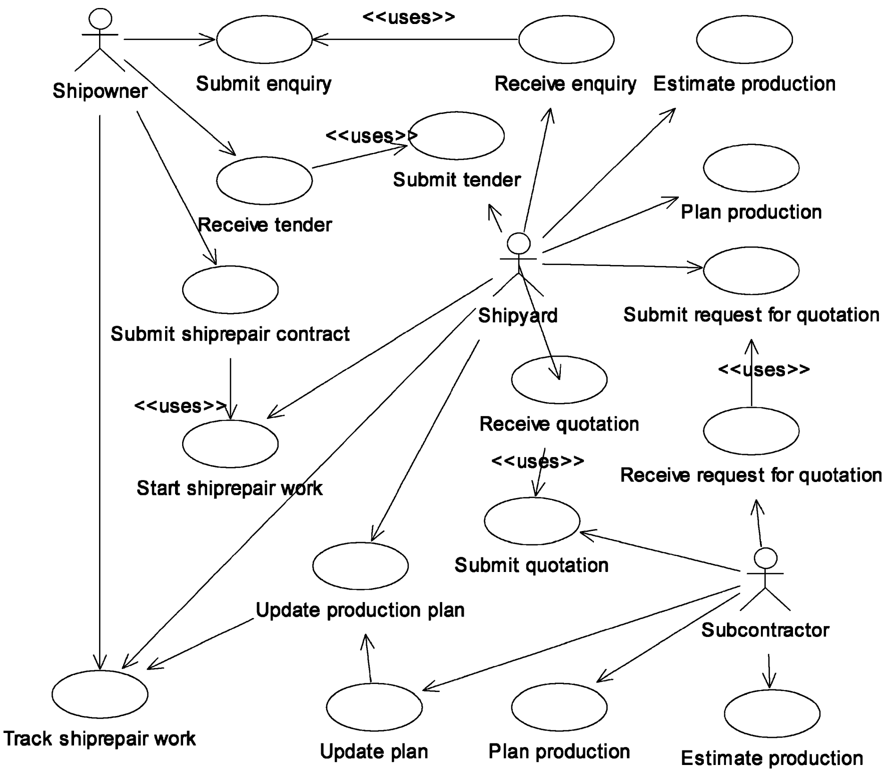

Fig. 1 Partners interactions in the shiprepair virtual enterprise [7]

- The partners in the virtual enterprises are individuals and independent companies who come together and form a temporary consortium to exploit a particular market opportunity. Within the scope of collaboration, partners share vision and work towards shared goal.
- Partners in virtual enterprises make extensive use of ICT technologies for communications and sharing information. Most of the day-to-day information exchange among the partners will almost always be automatic and without human interference.
- Virtual enterprises assemble themselves based on cost effectiveness and product uniqueness without regard to organization size or geographic location.
- Unlike the Supply Chain or the Extended Enterprise, virtual enterprises once formed will have a unique dynamics, new identity and quiet possibly a new name.
- The efficiency of the virtual enterprise is greatly determined by the speed and efficiency with which information can be exchanged and managed among business partners. Efficient collaborative engineering, production and logistics require effective electronic management of engineering and production information. Thus it is a prerequisite that participating enterprises have sufficiently sophisticated IT and decision support tools and mechanisms to make the integration possible.

- Virtual enterprises are often complex networks where each enterprise can be seen as a node.
- The relationship between nodes in virtual enterprise will mostly be non-hierarchical in nature.

3 Modelling the Virtual Enterprise

For being able to run a Virtual Enterprise the interaction among the business partners needs to be identified. The work process from the initiation of the common task to its end need to be documented including the roles of all partners, tools to support the activities, and any input to and output from the activities.

3.1 Business Process Modelling

UML is used extensively as a rather standard approach to represent business processes. Chryssolouris et al used the UML to model the sequence of interactions within the virtual enterprise [7]. The customer that is the ship owner, interacts only with the shipyard, Fig. 2.

Then the shipyard takes the responsibility to organize the work with the cooperating companies that are represented by the role of the subcontractor. The business process is modelled in Fig. 2 is as follows [5]:

- The Ship owner sends an Enquiry to the Shipyard, giving abstract information for the repair, for example that it is a Planned Maintenance and a few details about the ship, for example the size and weight.
- The Shipyard then decides if they can do the work, if they have the appropriate equipment (big enough docks) and if they have previous experience with the Ship owner and they ask ford detailed information.
- The Initial Work List is sent from Ship owner to the Shipyard. The Shipyard performs an estimation of the work to be performed.
- The Shipyard produces a Tender. The tender is actually a list of quotes on the work specification to the Ship owner.
- The Tender is forwarded to the Ship owner for processing and either acceptance or comments. Negotiations are reflected on the work list and the prices. The Ship owner accepts the Tender, the Initial Contract is signed between Ship owner and the yard according to the Tender.
- The ship arrives at the yard and repair work is initiated. During the repair the work list is continuously updated to reflect actual work done. New items are attached to the Initial Contract and others are Cancelled.
- When the shiprepair work has finished, the Invoice is sent by Shipyard to Ship owner.

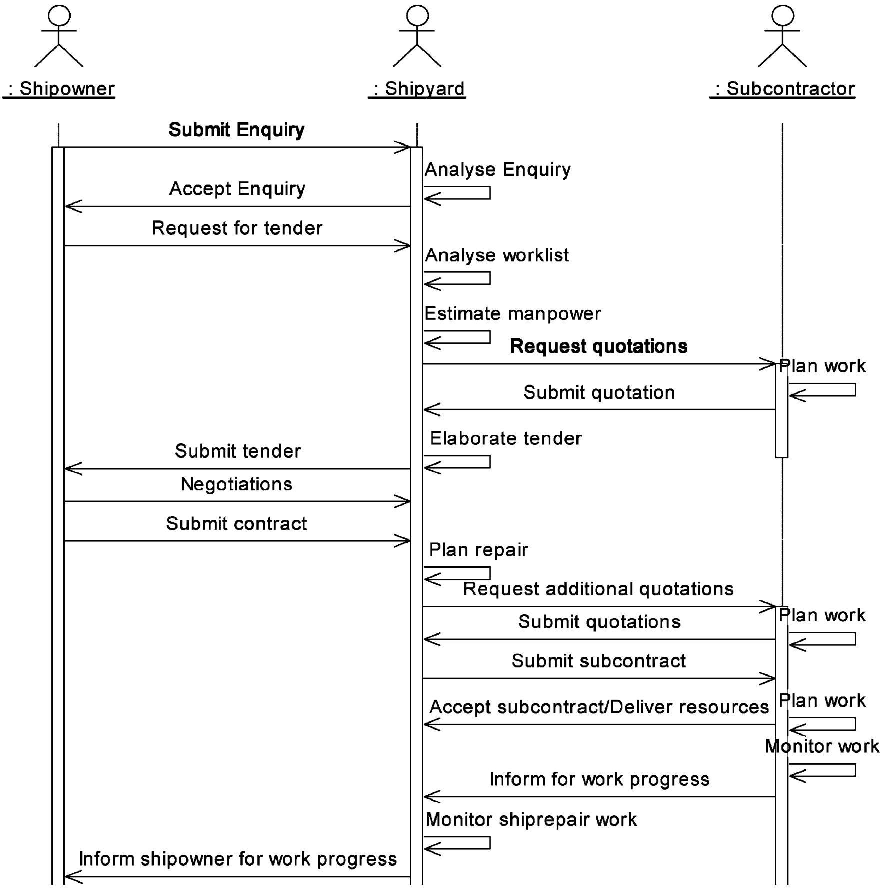

Fig. 2 UML sequence diagram for the shiprepair virtual enterprise [7]

3.2 Data Modelling

It is evident that as the number of partners within the virtual enterprise increases, the number of software systems that cooperate within the supply chain increases accordingly. The software systems used in the process must be flexible in terms of the information that exchange. They have to be able to plug in-plug out to the process independently of the specific software systems that participate in the supply chain. Thus, in this case, open standards are used that allow for seamlessly switch to another trading partner when necessary. A set of standards has been used to facilitate the data exchange in the virtual enterprise.

Over the years, formal information modeling languages have been developed facilitating the development of a large scale, networked, computer environments that behaves consistently and correctly [12]. These information-modeling languages

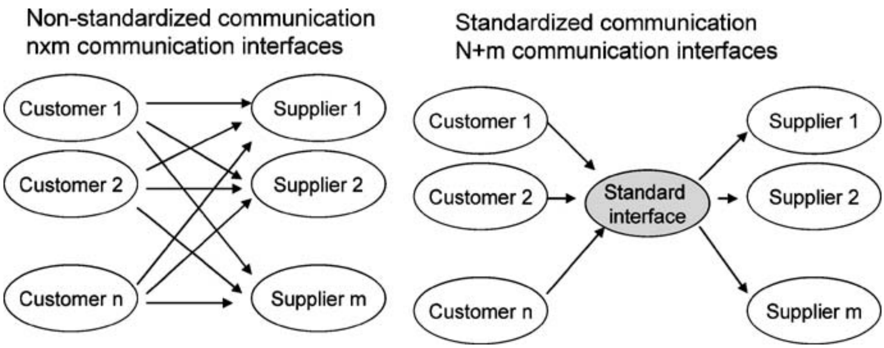

Fig. 3 Standardized versus non-standardized interfaces

provide ways for constructing a blueprint of the organization's data needs, called a data model. More specifically, a data model is a structured representation of business exchanged data. The primary goal of developing a data model is to build up and document an understanding of the relevant data from a business' perspective as well as to provide the means to document the business meaning of the data, the business reasons for capturing those data, and the business relationships among portions of data. This work discusses the data modeling of a shipyard organization inside a Maritime Virtual Organization.

An international effort for standardizing the representation of product information in order to support the life cycle of products in diverse industries, ISO 10303, informally STandard for the Exchange of Product model data – STEP [9], has been under way and is led by the International Organization for Standardization. The National Institute of Standards and Technology (NIST) has also launched two large programs, System Integration of Manufacturing Applications – SIMA [21] and National Advanced Manufacturing Testbed – NAMT [22], to support the U.S. industry in the area of information-based manufacturing. The SIMA Program seeks to provide U.S. manufacturers with capabilities enabling contextually meaningful data to be shared among business activities in such a way so as for the information to be reliably accessible when and where it is needed. NAMT is an effort to build a showcase for the future of manufacturing that will demonstrate how U.S. manufacturers and their suppliers can rapidly introduce both affordable and quality products. The United Nations Electronic Data Interchange for Administration Commerce and Transport [23] is a set of internationally agreed syntax standards, directories and guidelines for the structuring and exchanging of data, depicted in character format, among independent computer systems. The International Marine Purchasing Association – IMPA is a working group of ship owners, managing and operating companies, suppliers and manufacturers in the shipping industry [24]. It was founded in 1997 in order to improve the communication between purchasers and suppliers within the maritime business. As a result of these efforts, IMPA has developed a communication standard for trading in the shipping industry called Electronic Trading Standard Format – ETSF. The ETSF approach is based on the Internet technology and the UN/EDIFACT standard.

ISO 10303-28 is a part of the implementation methods of STEP with the official title “XML representation of EXPRESS schemas and data”, also called STEP-XML. XML is a subset of ISO 8879 Standard Generalized Markup Language – SGML that has been specified to enable generic SGML to be served, received, and processed on the World Wide Web. It provides syntax for constructing XML documents where the content of the XML document may be structured information as well as, or instead of, free text [10].

The eXtensible Markup Language – XML is designed to provide data, an avenue to the World Wide Web, enhancing other document description languages such as the HyperText Markup Language – HTML that is not so flexible in the definition of information in data models. Additionally, XML can be used to automate business documents, but it can also serve as a rich messaging format, even for inter-process communication. XML can even be a low cost substitute for complex EDI, CORBA technologies [18].

Markis et al. discuss a combined usage of STEP and XML based on the ISO 10303 Part 28 specification. ISO 10303-28 specifies means by which schemas specified using the EXPRESS language can be represented as an XML document [14]. This approach combines both the benefits of STEP and XML. STEP has the benefit that standardisation efforts have resulted to a wide range of models, including data models for almost all manufacturing sectors, including maritime. Therefore there is a rich set of models that already represent information related to mari-

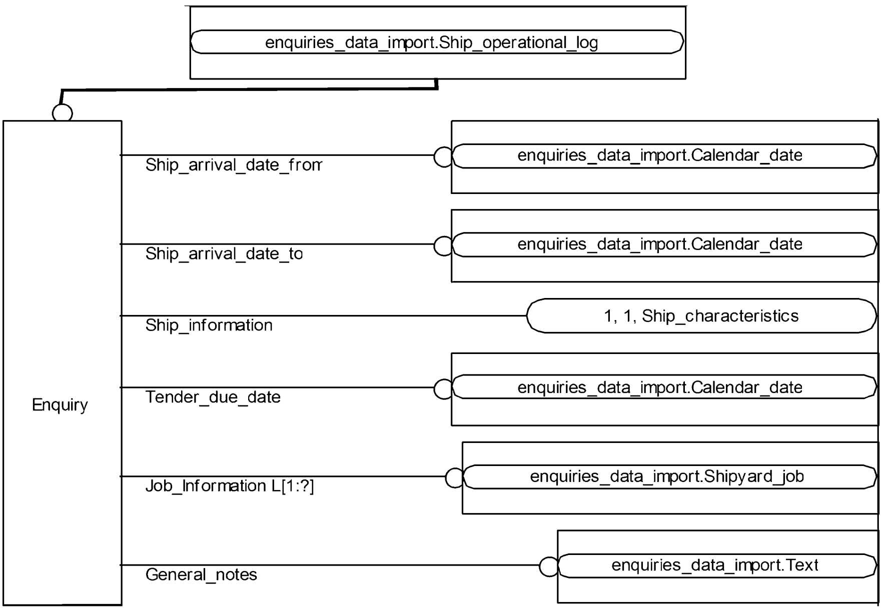

Fig. 4 The graphical representation of the Enquiry model in EXPRESS-G [14]

time, namely the maritime building blocks. On the other hand, simply said, XML offers a simple and elegant way to facilitate information exchange over the World Wide Web. First a STEP model is structured using the EXPRESS modelling language. This model is based on pre-existing models, the so called building blocks [20]. The EXPRESS-G model for the exchange of Enquiry data is shown in Fig. 4.

Having the model in EXPRESS format, the next step is to transform this model to its XML equivalent. Given an EXPRESS schema, and applying a set of instructions for defining an XML markup declaration set for the schema [10] The resulting XML model is based on a Data Type Declaration, according to the part 28 specification. Therefore, the entities and attributes defined in the EXPRESS model are then mapped to the respective elements and attributes of the XML formatted model. A simple example for the procedure that was described is shown in Fig. 5, where an EXPRESS model representing the name of a person is converted to its XML equivalent following the instructions of Part 28.

Following the above described procedure, the data of the ship owner applications are translated to XML neutral format. The XML formatted data are written according to the ISO part 28 data model specification. Then, these data are transmitted through the Internet, to the Shipyard for further processing. Finally, an interface translates the XML formatted data to the format required by the shipyard's software system. In a general case, more shipyards could receive enquiries and each one of them could make requests for quotations to more than one supplier, as shown in Fig. 6, by creating a supply chain network of cooperating partners.

EXPRESS model	**XML part 28 mapping**
SCHEMA persons;	<schema_decl>
ENTITY person;	<schema_id>
name : STRING;	persons
END_ENTITY;	</schema_id>
	<entity_decl>
END_SCHEMA;	<entity_id>
	person
	</entity_id>
	<explicit_attr_block>
	<explicit_attr>
	<attribute_id>
	name
	</attribute_id>
	<base_type>
	<string/>
	</base_type>
	</explicit_attr>
	</explicit_attr_block>
	</entity_decl>
	</schema_decl>

Fig. 5 Mapping EXPRESS to XML [14]

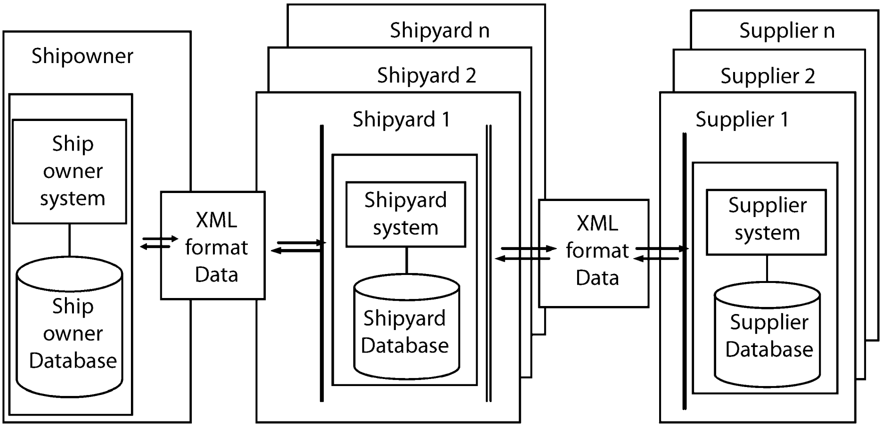

Fig. 6 The generic value added chain communication model [7]

There is also the possibility for modeling data using the UML approach, utilizing the class diagrams. This would provide an integrated way of including the data structures in the same model with the business process models. However, the UML has not been used extensively in data modeling. The STEP and other methodologies described previously have been used extensively to model the data in numerous industrial sectors, and provide a huge repository of data models that is easily reusable by adapting the above mentioned techniques.

Bhandarkar focused the effort to the support of the STEP standard with the development of a standards-oriented form-feature extraction system. The developed feature extraction system takes as an input a STEP file defining the geometry and topology of a part and generates as output a STEP file with form-feature information in AP224 format for form feature-based process planning. An algorithm is developed for prismatic solids produced by milling operations and that contain elementary shapes such as plane and cylindrical surfaces. The system can also be interfaced with a recent IGES to AP202 translator to allow conversion of legacy data [3].

Yoo and Kim state that among the large sets of specifications of information standards, those shown in Fig. 7, play a major role for virtual enterprises [26]. This research adapts STEP for product data, SGML/XML for documents and EDI for Electronic Commerce. As an example, a robot division of an engineering company is considered. The robot division designs and produces robot grippers based on outside orders. Sometimes parts of the work are subcontracted to the other companies. This division consists of a business team, a CAD/CAM team, and an assembly team.

The business team receives orders and delivers products, the CAD/CAM team designs the products and generates CAM data, and the assembly team manufactures the end products. A usual case of simplified workflow for this division is as follows:

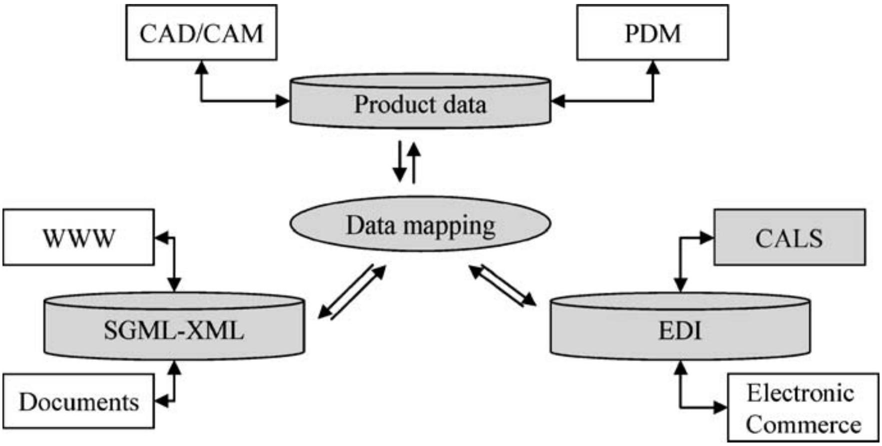

Fig. 7 Three major data exchange standards in virtual enterprise environments

a. Buyer's request is accepted in the business department.
b. The CAD/CAM team starts design process.
c. Send the completed design and Bill of Materials (BOM) to the assembly team.
d. Outsource parts if available.
e. Assemble and ship the products.

In virtual enterprises, all the inter-company communications (Steps (a), (c), and (d)) are performed via networks using EDI or internal documents. Upon receiving an order, the engineers in this company design the product first. In Step (b), the engineer searches the internal or external design DB first in order to locate existing designs that are similar to the current order. Using the metadata interface, the engineer finds similar designs in as many respects as possible, e. g., name of product, function description, technical specifications, and date. This search can be further more effective through the expansion of the keywords using ontology as explained in the previous section. In Step (d), the engineer also searches available parts from external part DB's, where metadata and ontology can be applied in a similar fashion. Once an existing design is found or new design is made, the design information can be translated into EDI or internal documents.

In Fig. 8, an Enquiry is created for the repair of a ship. These data have to be exported and transmitted to a shipyard. This is done by the use of a software interface using XML data, as seen in Fig. 9.

In [14] an implementation for transferring XML data to legacy databases is discussed. A software application is developed that is able to read enquiry data that are stored in an XML formatted document, identify the document structure and map the XML document elements to entities residing in the database of the legacy system, thus implementing a bridge from an XML file to a legacy system. Additional transformations are possible, by reading XML formatted files and mapping them to database entities and vice versa.

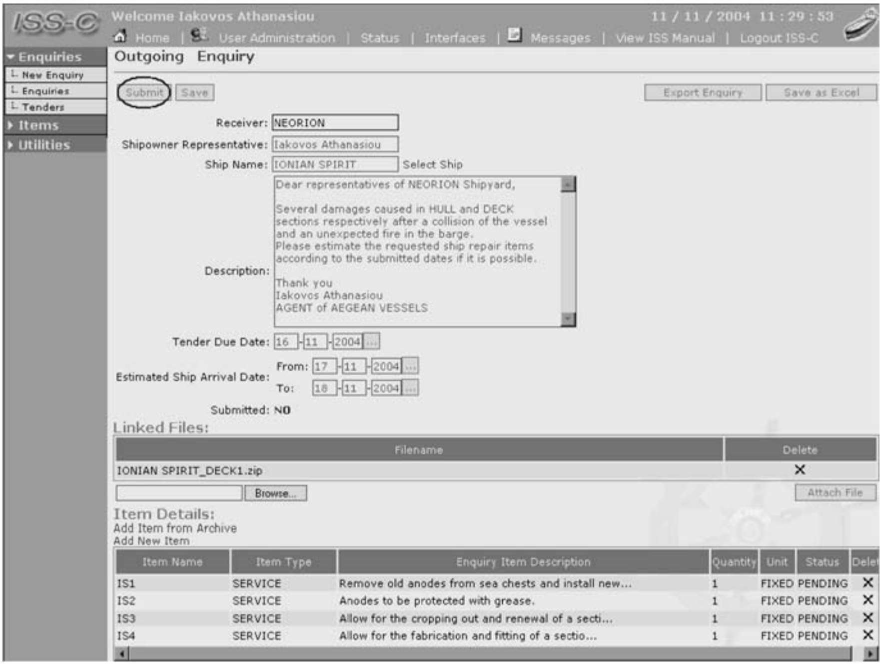

Fig. 8 Creating an outgoing enquiry for costing a ship repair

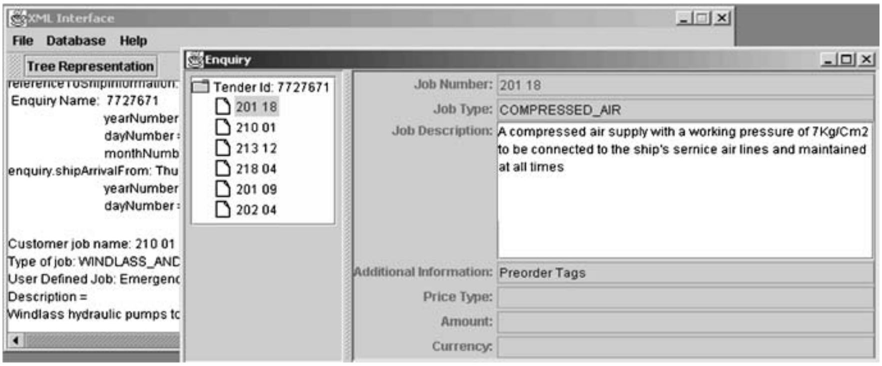

Fig. 9 Example of bridging XML formatted production data with legacy database [14].

3.3 Web Based Applications

The architecture that lies behind web based applications is the so-called 3-tier architecture. Its main advantage is the separation of functionality from the presentation layer, thus providing a better understanding to the developers, while leading

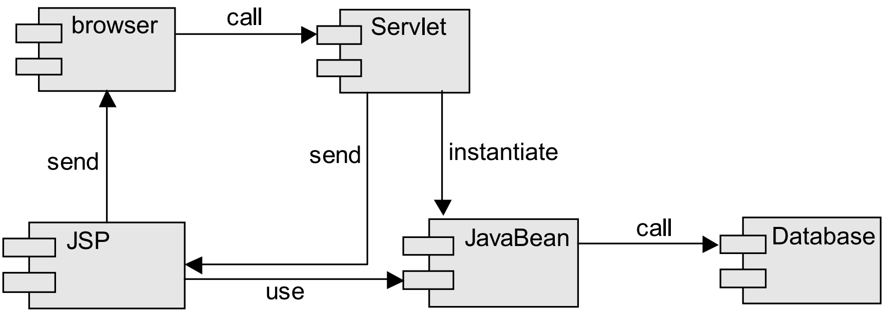

Fig. 10 Model view controller implementation [5]

to well defined components and limiting the software changes, throughout its life cycle. This approach involves a "Presentation" layer, an "Application" layer and a "Data" layer. The "Presentation" layer implements the "look and feel" of an application. The "Application" layer implements the business logic of the application and the "Data" layer manages the persistence (storage) of information.

Technologies that are quite popular in enterprise computing are the so called "Servlets", which make it easier to implement server-side applications using Java technology. Combined with "Java Server Pages", it is possible to generate data-based content [25].

In Fig. 10, the Servlet delegates the collection of data for the request to a Java Bean. The Java Bean collects the needed data to satisfy the request, by making calls to enterprise components like Enterprise Java Beans and databases, and when

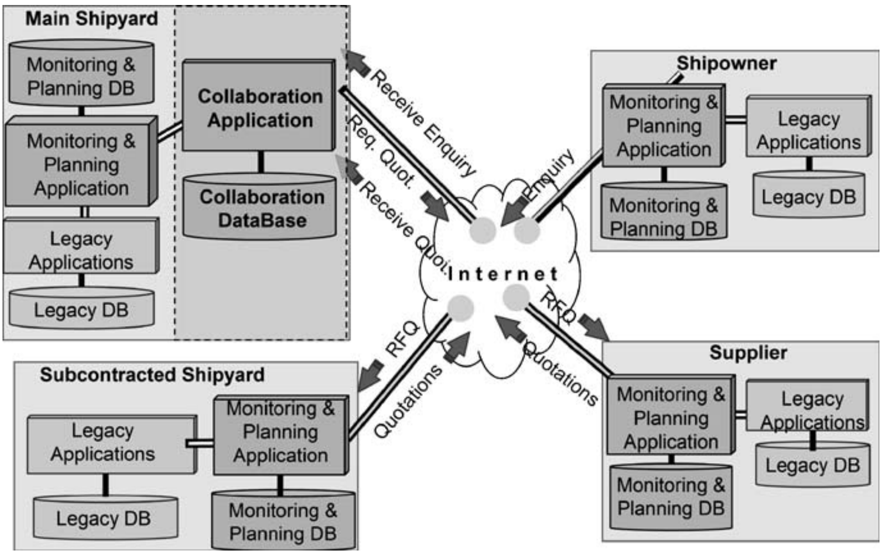

Fig. 11 Software modules deployment in the extended enterprise [5]

it is finished collecting the needed data returns control back to the Servlet. The Servlet then forwards the request to the JSP, which constructs the HTML response using the data from the Java Bean and its own HTML code. After construction, the response is sent to the browser for display.

In [5], a web based software package was developed that consists of two individual though complementary modules, the Collaboration and the Monitoring-Planning module. Fig. 11 demonstrates a generic cooperation scenario, where a customer submits an enquiry, the producer receives it and requests details, the customer then receives the request, in a similar way, requests and quotations are exchanged with suppliers and subcontractors via the Internet enabled software system.

3.4 Multi Agent Systems

Multi agent systems have been utilized to support the management of knowledge in terms of modeling rules of partners interactions. In [17] a multi agent system is suggested that is composed of a set of "processors" (nodes in a network of manufacturing resources), each one with its own particular capabilities, that has to exchange and process information in order to contribute to finding a solution to the global scheduling problem.

Turofski support that data exchange between manufacturers and their suppliers can be handled efficiently and in a timely manner using e-commerce techniques paired with agent technology. This approach can further help to coordinate distributed production processes. The use of technology enabling communications such as protocols (e. g. transport control protocol – TCP, hypertext transfer protocol – HTTP), or platform-independent programming languages (e. g. Java), across organizations using heterogeneous application systems is necessary, but not sufficient for mass customization (MC). Only combining ecommerce techniques with EDI or EDI related technologies such as standardized data exchanges. makes the links between manufacturers and suppliers efficient and responsive, as manual interfaces can be omitted and costs reduced [19].

Gou et al. developed a research on virtual enterprise operation into a framework for VE operation management. As shown in Fig. 12, the framework provides a well-defined system that can realize business integration for virtual enterprises. The figure also contains the other two levels of virtual enterprise integration (i. e. VE application integration and VE physical system integration), which provide basic supporting structures for VE business integration [8].

Wang et al. describe that agent-based technology provides the workflow coordination at both inter- and intra-enterprise levels while Web service-based technology provides infrastructures for messaging, service description and workflow enactment. A proof-of-concept prototype system simulating the order entry, partner search and selection, and contracting in a virtual enterprise creation scenario is implemented to demonstrate the dynamic workflow definition and execution for

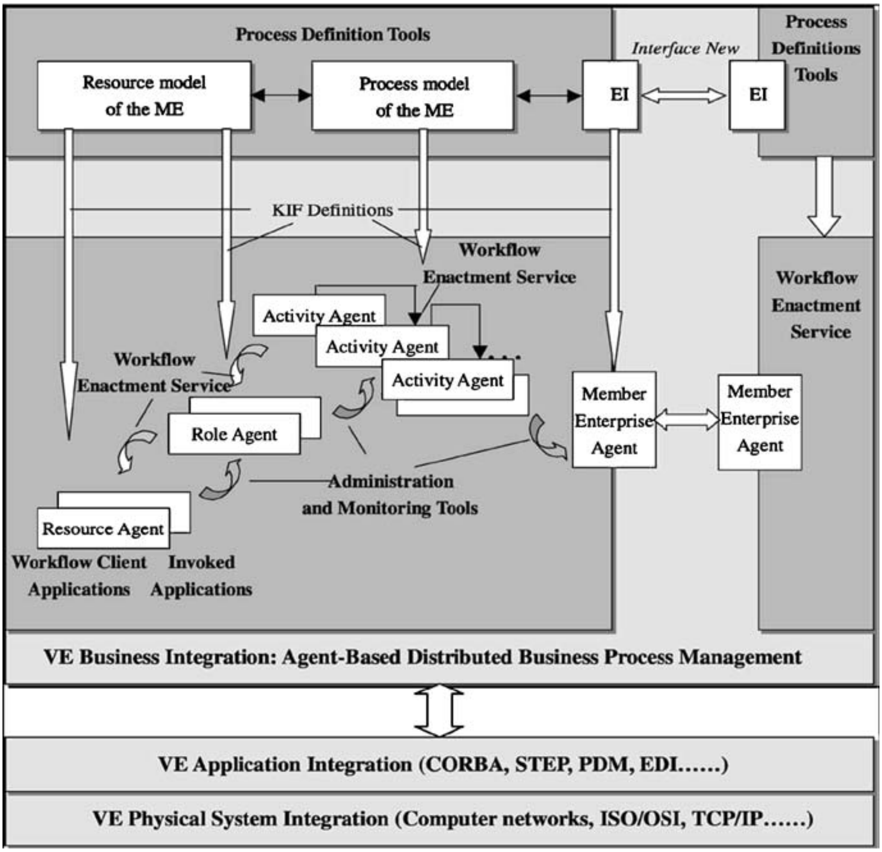

Fig. 12 A framework for VE operation management [8]

inter-enterprise collaboration. In the implemented prototype system, the Web services technology is utilised. Specifically, the Web portal, broker agent, UDDI server are implemented on one computer and three supplier agents' Web portals and Web services are running separately on three other computers [27].

The Web portals and Web services are developed using the Java Web Services Development Pack (SUN, JWSDP). It is a superset of Java XML package. The main software tools for system implementation are:

- Java APIs for Web services such as JAXP, JAXM, and JAXR.
- Tomcat as a Web portal test environment for Java Servlet or JSP.
- JSSE (Java Secure Socket Extension) for secure Web connections.
- Ant build tool for platform-independent build management.
- Java WSDL registry server which is a private UDDI server that can be deployed internally for service publication and discovery.

For simplicity of implementation, functions of the workflow planner agent are combined into the broker agent. The user places an order through a Web portal. The broker agent, which is implemented also as a run-time workflow engine, has the functions of service discovery, coordination and mediation. The broker agent searches the ontology agent, negotiates with supplier agents, and provides supplier bids to the customer. However, the decision of bid selection and order contracting depends on the choice made by the customer in the current prototype.

After the customer selects the best order bid based on his knowledge and the award is accepted by the chosen supplier agent, a contract is generated automatically with the proposed cost, quality, and time schedule in the bid. The contract can be seen from the Web portal and each chosen supplier will receive a copy once it is confirmed.

As for service discovery, only the UDDI is implemented for ontology agent to search about. Several organizations (supplier agents) together with services, descriptions, and service binding information are registered on the UDDI server.

In a similar way, Makris et at., exchange web based messages regarding arrival and completion date, specification of work and other details for a shiprepair, utilising web based data exchange that is coordinated by a well-defined business flow [13] as can be seen in Fig. 13.

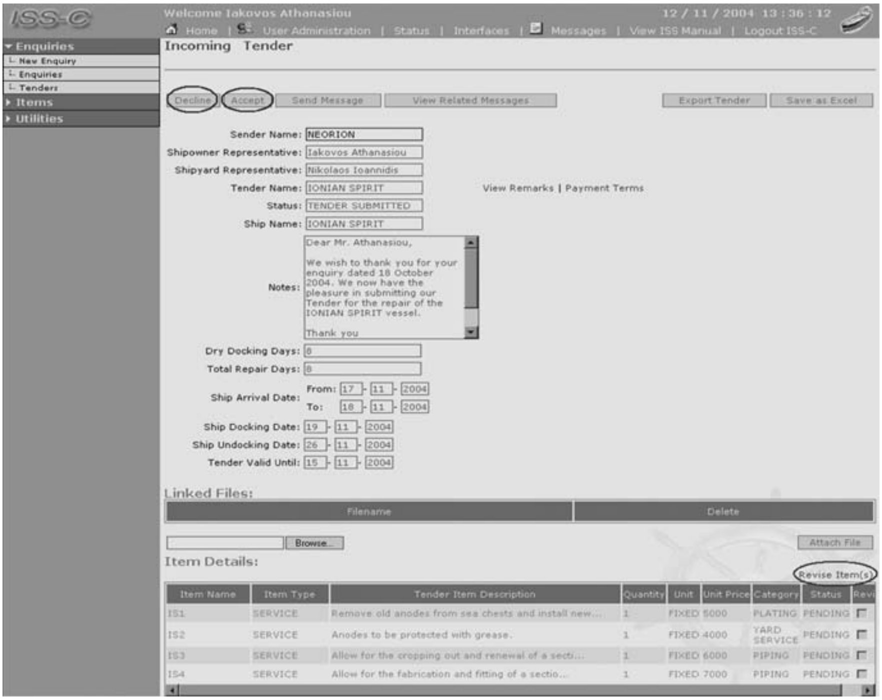

Fig. 13 Web based tender confirmation in shiprepair contract negotiations [13]

4 Conclusion and Outlook

The work discussed here demonstrates the major approaches that have been developed in the academia and their industrial application. Basic elements of this research include modeling of the business processes that take place in the virtual enterprise. It also includes methods for modeling the exchanges of data and demonstrates the modeling of the exchanged data by using the STEP and XML protocols that are the major ones used nowadays. Additionally, the business process and data exchange models are utilized in the form of web based software systems capable of materializing an efficient virtual enterprise coordination mechanism. Such systems are demonstrated that enable the efficient execution of the business process and the reliable exchange of business data. Additional concepts such as the integration of multi agent systems, implemented in the form of web services or other similar technologies, have been discussed and demonstrated in the form of representative industrial cases.

Difficulties in today's industrial environments have appeared concerning the infrastructure of the companies that participate in the virtual enterprises, which seem not to be ready yet to adapt high tech solutions due to the cost of internet connections and mainly due to lack of familiarization with use of computers. However it is believed that these burdens are only temporary and in the next years use of computers will be possible by everyone.

References

1. Aerts ATM, Szirbik NB (2002) Goossenaerts, JBM., A flexible agent-based ICT architecture for virtual enterprises, Computers in Industry, 49, 311–327.
2. Alhir, Sinan Si, (1998) UML in a nutshell – a quick desktop reference; O'Reilly.
3. Bhandarkar MP, Nagi R (2000) STEP-based feature extraction from STEP geometry for Agile Manufacturing, Computers in Industry, 41, 3–24.
4. Chryssolouris G (2006) Manufacturing Systems Theory and Practice. Springer-Verlag, New York, 2nd edition.
5. Chryssolouris G, Mourtzis D, Makris S, Papakostas N (2005) e-Collaboration for ship repair supply chain management, Proceedings of the 10th IEEE International Conference on Emerging Technologies and Factory Automation, Catania, Italy, 713–718.
6. Chryssolouris G, Makris S, Xanthakis V, Mourtzis, D (2004) Towards the Internet based Supply Chain Management for ship repair industry, International Journal of Computer Integrated Manufacturing, 17, 45–57.
7. Chryssolouris G, Makris S, Xanthakis V, Konstantinis V (2003) An XML based implementation of the Value Added Chain in Manufacturing: A Ship repair Case Study, CIRP Journal of Manufacturing Systems, Vol. 32, No.6, pp. 507–511.
8. Gou H, Huang B, Liu W, Li X (2003) A framework for virtual enterprise operation management, Computers in Industry, 50, 333–352.
9. ISO 10303-1 (1994) Industrial Automation Systems and Integration – Product Data Representation and Exchange – Part 1: Overview and Fundamental Prnciples.
10. ISO/PDTS 10303-28. ISO TC184/SC4/WG11 N140 (2000) Product data representation and exchange: Implementation methods: XML representation of EXPRESS schemas and data.

11. Jagdev HS and Thoben KD (2001) Anatomy of enterprise collaborations, Production Planning and Control, Vol. 12, No. 5, 437–451.
12. Lee TY (1999) An Overview of Information Modeling for Manufacturing Systems Integration. NISTIR 6382, Manufacturing Systems Integration Division National Institute of Standards and Technology, Gaithersburg. MD.
13. Makris S, Mourtzis D, Papakostas N, Chryssolouris G and Gaviotis I (2005) An e-Collaboration Software Framework for the Ship Repair Supply Chain, Proceedings of the 12th International Conference on Computer Applications in Shipbuilding (ICCAS), Busan, Korea, pp. 717–727.
14. Makris S, Xanthakis V, Mourtzis D, Chryssolouris G (2007) On the information modeling for the electronic operation of supply chains: A maritime case study, to be published in the Robotics and Integrated Manufacturing.
15. Odendahl C, Wieland P, Weitzenbock E, Jaramillo D, Makris S, Cacho A, Soares GC (2000) Marvin, a Virtual Enterprise Network for the Maritime Domain, Computer Applications and Information Technology in the Maritime Industries-COMPIT’2000, 323–14.
16. Perrin O, Godart C (2004) A model to support collaborative work in virtual enterprises, Data and Knowledge Engineering, 2004, 50, 63–86.
17. Rabelo RJ, Camarinha-Matos LM, Afsarmanesh H (1999) Multi-agent based agile scheduling, Robotics and Autonomous Systems, 27, 15–28.
18. Smith E (2000) Using XML for supply chain integration business case and technical issues. http://www.gca.org/papers/xmleurope2000/papers/s10-04.html.
19. Turowski K (2002) Agent-based e-commerce in case of mass customization, Int. J. Production Economics, 75, 69–81.
20. Turner T (1997) ISO TC184/SC4/WG3/N701 – AP Development Guidelines for Shipbuilding. Lloyd’s Register of Shipping.
21. URL SIMA. http://www.mel.nist.gov/div826/msid/sima/sima.htm, 2005.
22. URL NAMT. http://www.mel.nist.gov/namt/, 2005.
23. URL UN/EDIFACT. http://www.unece.org/trade/untdid/welcome.htm, 2003.
24. URL IMPA_ETS. http://www.spectec.co.uk/impa_ets/index.htm, 2003.
25. URL sun.com, http://java.sun.com/developer/technicalArticles/xml/WebApp Dev/, 2004.
26. Yoo SB, Kim Y (2002) Web-based knowledge management for sharing product data in virtual enterprises, Int. J. Production Economics, 75, 173–183.
27. Wang S, Shen W, Hao Q (2006) An agent-based Web service workflow model for inter-enterprise collaboration, Expert Systems with Applications, 31, 787–799.

Further Reading

- Shapiro JF (2001) Modeling the Supply Chain, (Duxbury, Thomson Learning Inc.
- URL XML, http://www.xml.com/pub/a/98/10/guide0.html?page=2#AEN58, 2005.
- Chryssolouris G., Papakostas N., Makris S. and Mourtzis D.(1999) Planning and Scheduling of Shipyard Processes, Application of Information Technologies to the Maritime Industries, C. Guedes Soares, J. Brodda (Eds.), 255–274, ISBN: 972-689-157-4.
- Chryssolouris, G., D. Mourtzis and S. Makris (2003) An Approach to Planning and Control of Ship Repair Manufacturing Operations, CIRP Journal of Manufacturing Systems, Vol. 32, No.1.
- Chryssolouris, G., Bechrakis, K., Makris, S., Xeromerites, S., Mourtzis, D., Papakostas, N. (1999) A Planning and Control Method for Shipyard Processes: A Shiprepai Yard Case Study, Proceedings of 10th International Conference on Computer Applications in Shipbuilding (ICCAS99), MIT, pp. 127–135.
- Jaramillo, D., Haenisch, J., Makris, S., Weitzenbock, E. (2000) Validation of the Product Data Model for Ship Operation, PDT Europe 2000, Noordwijk, pp. 323–330.

- Odendahl, C., R. Angeli, J. Haenisch, D. Jaramillo, S. Makris and E. Weitzenbock, (2000) Web-based Virtual Enterprise Network for the Maritime Industry, Proceedings of the e-business & e-work, Conference and Exhibition, Madrid, Spain, pp. 559–565.
- Quatrani, T., (1998) Visual Modeling with Rational Rose and UML, Addison-Wesley.
- Chryssolouris, G., Mourtzis, D., Makris, S. (2001) An Approach to Planning & Control of Shiprepair Manufacturing Operations, Proceedings of the 34th International CIRP Seminar on Manufacturing Systems, Athens, Greece, pp. 11–16.
- Chryssolouris, G., S. Makris, V. Xanthakis and V. Konstantinis, "An XML based implementation of the value added chain in Manufacturing: A ship repair case study", Proceedings of the 34th International CIRP Seminar on Manufacturing Systems, Athens, Greece, (May 2001), pp. 389–392.
- Chryssolouris, G., S. Makris, N. Papakostas and V. Xanthakis, "A cooperative software environment for planning and controlling ship-repair contracts", Proceedings of the 4th International Conference on e-Engineering & Digital Enterprise Technology, Leeds Metropolitan University, UK., (September 2004), pp. 321–330.
- Chryssolouris, G., Makris, S., Papakostas, N., Mourtzis, D. (2004) An integrated software framework for synchronizing internal business functions of a ship-repair yard, Proceedings of the 4th International Conference on e-Engineering & Digital Enterprise Technology, Leeds Metropolitan University, UK, pp. 255–264.
- Makris, S., Mourtzis, D., Papakostas, N., Chryssolouris, G. Gaviotis, I. (2005) An e-Collaboration Software Framework for the Ship Repair Supply Chain, Proceedings of the 12th International Conference on Computer Applications in Shipbuilding (ICCAS), Busan, Korea, pp. 717–727.
- Makris, S., Mourtzis, D., Papakostas, N. Chryssolouris, G. (2005) e-Collaboration for Ship repair Supply Chain Management, Proceedings of the 10th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA 2005), Catania, Italy, pp. 713–718.
- Wall, M. (1996) A Genetic Algorithm for Resource-Constrained Scheduling, PhD Thesis, Department of Mechanical Engineering, Massachusetts Institute of Technology.