

Advances in Electronic Business Volume I

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Preface

Introduction

For years, the efficient data exchange between businesses has been an important issue in improving business transactions. The automation of placing purchase orders, acknowledging orders, sending invoices, initiating the payment process, and preparing documents to closely related supply chain partners has significantly improved business performance. Electronic document interchange (EDI) seemed to carry the mission in the 1980s. However, without surprise, the proprietarily formatted message of EDI shared via value-added network does not react to the challenge appropriately. On the other hand, keen business competition demands a new technology to replace the proprietary EDI system. Extensible Markup Language (XML) gaining popularity in the late 1990s seemed to answer to the call. The XML language uses text-based format and allows users to define their own message format. The message can be sent through the Internet and be manipulated by Java, where both Internet and Java are ready for global data exchange in a perfect timing.

At the same time, the technology for intra-business integration has matured as well. The enterprise resource planning (ERP) system integrating the business modules, such as inventory management, accounting information system, customer service, human resource, engineering, and manufacturing resource planning, provides the strengths of amalgamated financial data, standardized manufacturing process, and complete human resource information in real time. The ERP allows a company to manage resources while doing business with suppliers and customers. In the interaction between companies, the online catalogue becomes an interface. Traditionally, an online catalogue is a one-way ordering system for the customer to purchase products from suppliers. Today, since the

online catalogue has integrated with the back-end system in some companies, a customer can have more detailed information, trace the status of work-in-process orders, and, to an end, participate in the product design.

Nowadays, being the best in producing quality products is not good enough. The real e-business model is to streamline the supply chain with partners using an integrated internal ERP system. New technologies can further improve the supply chain. For example, GM uses radio frequency identification (RFID) to trace the shop-floor process and update the database via Wi-Fi wireless connection to manage their supply chain operations, and Wal-Mart uses to RFID to trace inventory.

When most companies enhance the competition from company versus company to supply chain versus supply chain, what is the next step a company should take? This book is written to echo the calls for advancing electronic business. The answer to companies is collaborative commerce. Collaborative commerce, as it will be defined in Chapter I, is (1) a collaborative technology, similar to workflow collaboration; (2) a customer-driven technology, similar to a pull-type supply chain; (3) a functionally integrated technology, similar to concurrent engineering; and (4) a business-driven technology, similar to enterprise resource planning, for cross-organizational integration. Therefore, in collaborative commerce, there are several activities involved: collaborative design, collaborative engineering, collaborative decision making, workflow collaboration, knowledge networking, and others. In fact, there are currently many efforts to provide the infrastructure for collaborative commerce. The most significant one is RosettaNet, which is a global consortium found in 1998 by more than 400 electronic components, IT, and semiconductor manufacturing companies to define and standardize e-business transaction processes among trading partners.

Book Organization

This book is organized in the following way:

Chapter I defines collaborative commerce and explains how companies use information technology to achieve a closer integration and a better management of business relationships among business partners.

Chapter II proposes a meta-taxonomy to classify the existing taxonomies of collaborative systems found in the literature using three dimensions in e-collaboration: communication, cooperation, and coordination.

Chapter III discusses the roles of electronic business solutions (EBSs) in supporting collaborative product development (CPD). Two fundamental questions are examined: when and where EBSs should be applied for what CPD decision

activities and how EBSs should be designed and developed to maximize their usefulness and usability in supporting CPD decision activities.

Chapter IV presents the evolution of concurrent engineering to extended enterprise collaborative engineering and introduces basic mainstays. The expansion of enterprise architectures using extended and virtual models is possible due to the advances of communication tools and the capabilities of computer-aided tools that heavily depend on the digital product representation.

Chapter V introduces the collaborative decision-making (CDM) framework as a means of systematically developing collaborative systems in an electronic business environment. It argues that the CDM framework provides a holistic view of the components that play critical roles for collaboration, which include group facilitation and coordination, knowledge repositories, dialectic decision support, and discussion strategy support.

Chapter VI focuses on a summary of the contemporary development of workflow management systems in collaborative commerce. The technical facet is demonstrated from perspectives of architectures, standards, and system analysis.

Chapter VII aims to describe interorganizational “knowledge networks” and demonstrate how they have ushered in a new paradigm of collaborative business by forging links between internal and external knowledge and information resources.

Chapter VIII introduces networked collaborative e-learning as a specific model of e-learning. It argues that any e-learning event or course is underpinned by a set of educational values which determine the design of that event, and networked collaborative e-learning is underpinned by a belief that e-learning communities and identity formation are central features of this form of learning.

Chapter IX examines various types of supply chain management information systems. It argues that the approach best suited for an organization depends in part on the degree of integration between the partners, the complexity of the business processes, and the number of partners involved.

Chapter X introduces the applications of collaborative transportation and consolidation management in global third-party logistics. These practices are driven by the quest to improve service and reduce cost simultaneously under an e-commerce model of global supply chain management.

Finally, *Chapter XI* deals with ethical dimensions in the environment of collaborative commerce. An ethical failure model is developed based upon failure concepts borrowed from the quality profession.

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Introduction

Many businesses today tie collaborative relationships between partners through the use of digital technologies. The level of collaboration has moved beyond buying and selling to planning, designing, developing, communicating, discovering information, researching, and providing services among organisations. This new form of collaboration is called collaborative commerce. Following the evolution of electronic business, collaborative commerce is defined as using information technology to achieve a closer integration and a better management of business relationships among parties, including internal personnel, business partners, and customers (Bond, Burdick, Miklovic, Pond, & Eschinger, 1999; Turban & King, 2003). In responding to ever-changing global market demand, business collaboration will bring the whole supply chain to a competitive edge by decreasing product development costs, shortening the time to market, and improving product quality.

A survey of more than 300 business executives by Deloitte Research in mid-2002 shows that collaborative commerce has led to better business operation and information exchange and has provided a 70% rise in profitability for those companies that adopted the technology compared with those that did not integrate with their trading partners (Ferreira et al., 2002). Similar results were found in a survey conducted by NerveWire (2002). Companies with a *very high*, that is, Level 4, external integration level appear to be more competitive in several metrics than those companies with lower integration levels. The average revenue of Level 4 companies increases by about 40%, which is about 3 times that attained by companies at Level 2 or 3. Moreover, cost reductions at Level 4 are about 2.5 times the average of those at Level 2. This is all because the integrated environment can enhance the value chain of suppliers, business partners, customers, and employees through flexible business processes, better product quality, rapid order fulfillment, improved reliability, improved capital efficiency, and prompt information exchange and knowledge sharing.

The applications of collaborative commerce are various, including promising areas such as collaborative design, collaborative engineering, collaborative decision making, collaborative forecasting, financial collaboration, sharing knowledge of human resources, collaborative inventory management, and consolidating transportation. Moreover, several collaborative models are well known today. For example, collaborative planning, forecasting, and replenishment (CPFR) by the Voluntary Interindustry Commerce Standards Association uses ERP and demand planning systems for collaborative facilities forecasting and planning. Collaborative forecasting and replenishment (CFAR), jointly initiated by Wal-Mart and P&G, provides no gap between what Wal-Mart plans to sell and what P&G plans to produce (Chopra & Meindl, 2001).

Chapter I

Collaborative Commerce¹

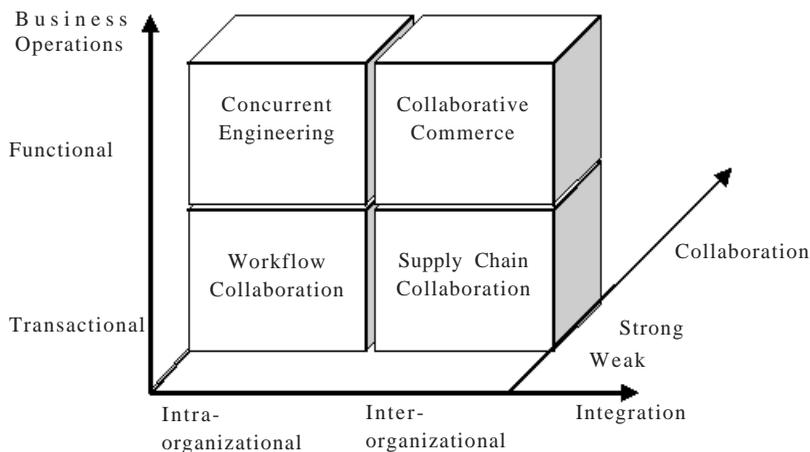
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Abstract

This chapter introduces collaborative commerce as a means of integrating information technologies into e-business adoption. It explains how companies use information technology to achieve a closer integration and a better management of business relationships among business partners, including internal personnel, business partners, and customers. In this chapter, collaborative commerce is defined as (1) a collaborative technology, similar to workflow collaboration; (2) a customer-driven technology, similar to a pull-type supply chain; (3) a functionally integrated technology, similar to concurrent engineering; and (4) a business-driven technology, similar to enterprise resource planning, for cross-organisational integration. The authors hope that understanding the characteristics and infrastructures of collaborative commerce can improve the adoption of the technologies.

Figure 1. Collaborative Commerce is an Evolutionary Technology



such as IBM, i2, SAP, AMR, and so on, were competing to provide ways of conceptualising their own way of enterprise collaboration over the Internet.

Although they varied in the way they implemented c-commerce, they were all clamouring for the rewards and the competitive edge brought about by the c-commerce business model. In general, collaborative commerce integrates business processes such as demand planning, planning and scheduling, order management, product development, vendor management, sales support, and knowledge sharing between partners through sharing information electronically (see *Figure 2*). Moreover, collaborative commerce is a set of techniques to allow companies to maintain better relationships with their trading partners through automating their cross-enterprise process logic, rules, heuristic, and workflow.

The emergence of the collaborative commerce model articulates the succession of continuous improvements in supply chain management. To continue maintaining the competitive edge of an enterprise in the digital economy, several efforts in improving business processes and operations have been made during the past decades. First of all, enterprises adopted enterprise resource planning (ERP) to centralize originally isolated information modules within an organisation. Such efforts resulted in the increase of information efficiency and integrity. Later, enterprises recognised the benefit of information transparency in the supply chain. Therefore, solutions for the exchange of valuable business information within the supply chain became the focus of efforts to manage supply chain performance. Such efforts reflect the benefit of information synergy on eliminating the bullwhip effect (Chopra & Meindl, 2001).

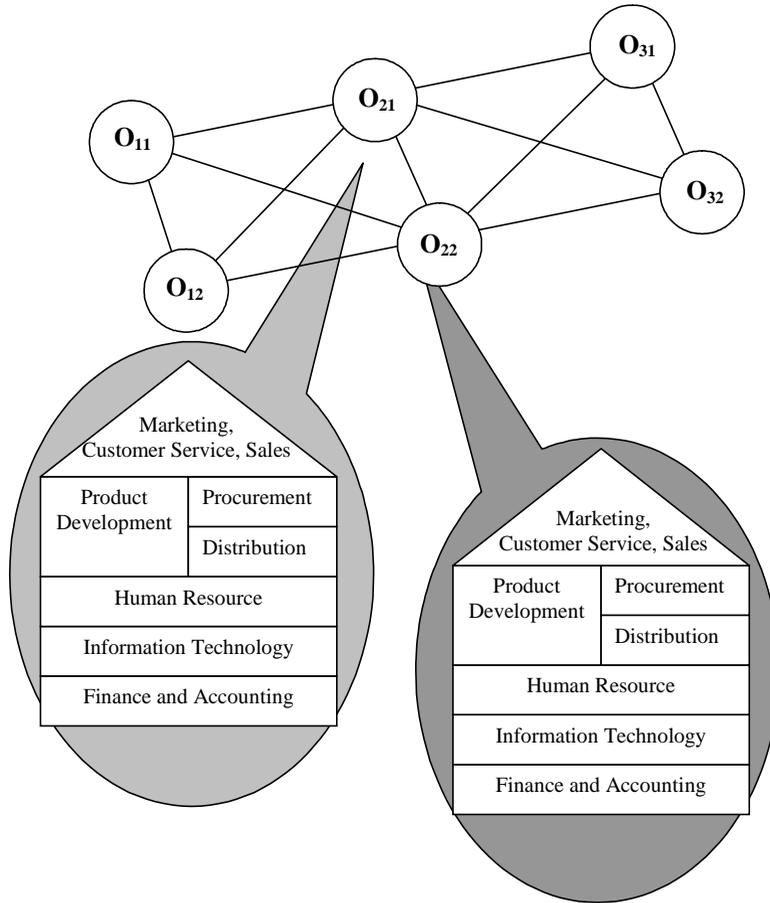
Two points need to be addressed better to understand collaborative commerce:

- (1) *Collaborative commerce is collaborative business.* Just as the terminologies *electronic commerce* and *electronic business* can be used interchangeably, the term *collaborative commerce* can be used interchangeably with *collaborative business*. Note that commerce describes the buying-and-selling transactions between parties. However, electronic business has a broader meaning in which more business operations, such as design, production, and transportation, are involved. However, these two terms are sometimes used interchangeably in describing business transactions via electronic media. Similarly, collaborative commerce is not limited to a collaborative development in buying and selling goods and services. It includes all levels of the activities of business operations.
- (2) *Collaborative commerce is an evolutionary technology.* Collaborative commerce evolves from collaboration in the workflow to concurrent engineering and the supply chain and beyond. Three dimensions can be used to describe the movement of these technologies: collaboration, organisational integration, and business operations (see *Figure 1*). Workflow collaboration is an improvement on individual efforts in business activities to stronger cooperation. However, most of these activities belong to the transactional type, which means that a task is assigned to an employee either after another employee has completed his or her task or concurrently with that employee. In contrast, concurrent engineering has a deeper collaborative involvement with the employees.

Concurrent engineering brings employees with different expertise together for product development. These activities involve more functional operations, such as product design, procurement, and human resources management. Recent technology in supply chain collaboration focuses more on interorganisational integration than on the workflow and concurrent engineering. However, the supply chain linking organisations together to share information is rarely involved at this functional level. Therefore, the trend towards moving workflow collaboration, concurrent engineering, and supply chain collaboration to a profound level of functional integration is apparent. This is the origin of collaborative commerce.

While the term *collaborative commerce*, abbreviated as c-commerce, was first coined by the Gartner Group in 1999 as the next trend of e-business models and IT investment in the B2B world, it was conceptualised as a new form of business model that had been enabled and leveraged by the Internet and integration technologies (Bond et al., 1999). Soon after Gartner's coinage of the term, major software vendors, including ERP vendors and individual B2B software vendors

Figure 2. Collaborative Commerce Integrates Business Processes Across Collaborative Partners O_{11} , O_{12} , O_{21} , O_{22} , O_{31} , and O_{32}



Recently, market and globalisation competition, customer-oriented service strategy, and product complexity have pushed enterprises a step further on in business collaboration. To outsource minor business functions effectively and focus on core competitiveness, enterprises need to integrate their information systems with external systems owned by their collaborating partners. In this way the information shared among partners and business processes could flow seamlessly from organisation to organisation. Such system integration brings multiple enterprises to collaborate in shared business opportunities.

In summary, collaborative commerce is (1) a collaborative technology, similar to workflow collaboration; (2) a customer-driven technology, similar to a pull-type supply chain; (3) a functionally integrated technology, similar to concurrent engineering; and (4) a business-driven technology, similar to enterprise resource

health care, telecommunication, manufacturing, and production (Bertino, Jajodia, & Samarati, 1999). To allow workflow collaboration across organisations, four elements need to be carefully designed: DBMS, WFMS, administration functions, and applications monitoring. The DBMS manages conventional database tasks, such as data maintenance, data integrity, concurrency control, and recovery of current data and historical data. The DBMS needs to manage data sharing among organisations. WFMS deals with the workflow process definition, activities, and control. Access to WFMS is across the collaborating organisations. This creates a high degree of complexity.

The applications provide services such as ERP, and its corresponding data are normally managed by DBMS. The sharing of applications involves the complexity of both the data level and the functional level. The administration and monitoring element handles administrative tasks that fall outside the scope of the DBMS and WFMS, such as statistical analysis, resource management, and operational management. This element also implements some access control mechanisms, especially those mechanisms related to other organisations. For example, collaborators may be allowed to refer to the statistical data of total sales rather than sales of individual items when designing a product collaboratively.

Customer-Driven Technologies

Collaborative commerce should be customer-driven, similar to the theme of the pull-type supply chain — pulled by the customer rather than pushed by the manufacturer. Note that the supply chain links organisations together to share information, products, and funds to fulfill their customers' requests efficiently. Supply chain processes can be identified as belonging to four cycles: the customer order cycle, the replenishment cycle, the manufacturing cycle, and the procurement cycle (Chopra & Meindl, 2001). A successful supply chain should be driven by the customer order cycle to the procurement cycle. The shorter the propagation channel, the quicker the response of the supply chain can be. The customer order cycle links customers with retailers to fulfill the customer's orders. The activities in the customer cycle include order entry, order fulfillment, and order receiving. The replenishment cycle focuses on replenishing the retailer's inventory by coordinating between retailers and distributors. Activities such as retail order entries, retail ordering, fulfillment of retailer's order, and receiving goods are involved. The activities between distributors and manufacturers are considered the manufacturing cycle. In this cycle, the replenishment of the distributor's inventory is the focal point. The activities include the arrival of the order from the distributor, retailer, or customer; the manufacturer's

planning, for cross-organisational integration. The following sections will illustrate the technologies followed by the infrastructure of system integration. Finally the critical success factors of collaborative commerce adoption will be discussed together with our conclusions.

Collaborative Technologies

Collaboration is the focal point in collaborative commerce. Traditionally the workflow is created to deal with specific *cases* in an organisation, such as mortgage applications and engineering tests. Each case has a unique identity and a limited lifetime. That is, a case should be completed within a certain time limit and will exit the workflow system when the work is completed. That also means that attributes are needed to describe the state and content of the workflow. The work in a workflow can be identified as *tasks*, which represent the indivisible units of works. The tasks are carried out by *processes*. When the processes are carried out in a workflow, they follow a specific sequence, which determines which tasks need to be performed next. There are four different types of sequences: *sequential*, *parallel*, *selective*, and *iterative* routings. Sequential routing confines one task to be executed before another task, while parallel routing allows two tasks to be performed without having any result on the other. Similarly, selective routing provides the choice between or among tasks, and iteration allows the same task to be performed more than once.

During implementation, the process needs to be enacted to perform a task. The enactment is triggered by *events*, such as external events (a new order having arrived), resources (an employee making a request), or time signals (at 8:00 a.m.; Aalst & Hee, 2002). Note that tasks are assigned to designated *roles* of an organisation following principles such as the separation of duties, least-privilege assignment, and data abstraction (Sandhu, Coyne, Feinstein, & Youman, 1996). These principles assure the successful implementation of the workflow. For example, the separation of duties assigns two sensitive tasks to two exclusive roles so that conspired perpetration can be avoided. On the other hand, the least-privilege policy, also called the need-to-know policy (Castano, Fugini, Martella, & Samarati, 1995), provides only minimum information for completing the task. In collaborative commerce, a number of organisations, including supply chain partners or even competitors, can collaborate in the workflow of an organisation. This implies that better control of access and degrees of collaboration are expected in collaborative commerce.

The workflow management system (WFMS) manages the workflow on a day-to-day basis in various application domains, such as office automation, finance,

production scheduling; the manufacturing and shipping of the item; and the receipt of the item by the distributor, retailer, or customer. The last cycle, called the procurement cycle, is the linkage between the manufacturers and suppliers. This cycle ensures that the materials are available for manufacturing by considering orders based on the manufacturer's production schedule or the supplier's stocking needs and the supplier's production scheduling and shipping.

There are many famous implementations of the concept of the supply chain. For example, in the customer order cycle, the online catalogue is a useful implementation for putting products online for customers. This provides significant advantages in giving up-to-date information to customers. Similarly, sales force automation (SFA) automates relations between sellers and buyers by providing product and price information. However, in the replenishment cycle, vendor-managed inventory (VMI) allows the distributor or manufacturer to manage inventories, and the wholesaler's or retailer's continuous replenishment programmes (CRP) allow suppliers to replenish the inventories of retailers regularly based on POS data. In the manufacturing cycle, advanced planning and scheduling (APS) develops the detailed production schedules about what to make, where to make it, when to make it, and how to make it by considering the availability of materials and plant capacity, among other business objectives. The objective of an organisation is to optimize the capacity of manufacturing, distribution, and transportation resources based on the data collected from ERP or legacy systems. In the procurement cycle, a content catalogue that focuses on the activities between the manufacturer and its suppliers can simplify the procurement process and allow the manufacturer to keep track of the parts, specifications, prices, and order processes of the suppliers.

However, to maintain the supply chain relationship, a high degree of trust is needed. In general, trust is nurtured from deterrence-based trust, knowledge-based trust, and identification-based trust (Turban & King, 2003). Deterrence-based trust uses a variety of formal contracts to ensure cooperation between parties, while knowledge-based trust is built on the knowledge of the other trading partner (trustee), which allows the trustor to understand and predict the behavior of the trustee. However, to build a strong relationship, identification-based trust, which allows each party to consider the other party's objective as identical to its own, is beneficial. The same idea is applied to collaborative commerce. Moreover, it should be noted that the partners in collaborative commerce also include competitors, which is not common in the supply chain. Therefore, the degree of trust and the need to do access control are especially important.

However, the organisation culture that emphasizes collaboration is the most important factor that glues together cross-functional integration. The same idea can be applied to collaborative commerce, which encourages cross-functional and cross-organisational collaboration. Both the hard factors, such as the five mechanisms, and the soft factor, that is, the collaborative culture, are all critical to success.

Business-Driven Technologies

Business-driven technology creates the possibility of better information technology adoption. Successful information technology adoption can be traced back to the history of the adoption of enterprise resource planning (ERP) against computer-integrated manufacturing (CIM). In the 1960s material requirement planning (MRP) was adopted by most manufacturers to find out “what are we going to make.” To deliver products to customers, the company needs to examine “what it takes” to make the products and “what we have now.” Then, if we do not have sufficient materials to make the products, we must decide “what we have to get.”

With a little help from computers, these questions were easy to answer in that age since the business operations were simple. However, gradually, the manufacturers wanted to manage both the quality and quantity of the products so that they could deliver them to happy customers on time. This requires an integrated shop-floor control system, which controls the activities of all resources through capacity requirement planning (CRP), scheduling, shop-floor control, and other mechanisms. That brings us to a full-scale shop-floor control system, called the manufacturing execution system (MES).

In the 1970s, the focal point of the manufacturers became how to integrate both MRP and MES so that they could manage orders as well as shop-floor production. The new system is called manufacturing resource planning (MRP II). The key to the success of MRP II is in the integration of individual modules and information flow. Fortunately, a new generation of both the hardware and software was evolved by the growth of information technology. This trend nourished the integration of MRP II. At the same time, parallel to the growth of MRP II, accountants found they needed to handle tasks more than just credit and debit data: they needed methods of internal control. Internal control provides a reasonable way of protecting the business process of an organisation from the misuse of assets. At that time, the accounting information system (AIS) delivered its promise and prevailed in service industries. It is not then surprising

Functional-Integrated Technologies

The degree of collaboration in collaborative commerce should go down to the level of functional integration, similar to that in concurrent engineering (CE) — a systematic approach to integrate product design and manufacturing process support to minimize product development time. Prasad (1996) conceptualised the functionalities for CE as two wheels. The first CE wheel represents the integrated product and process organisation, while the second concurrent wheel defines the integrated product design and development. Both wheels have three rings to represent the three essential elements of CE. The inner ring is the hub of the wheel and includes the four Ms: models, methods, metrics, and measures. Basically, the four M elements provide the fundamental methodologies for CE implementation. The middle ring focuses on the work groups that drive the wheel forward. The elements in the middle ring for both wheels are identical: personnel teams, virtual teams, logical teams, and technological teams. The centrality of these teams emphasizes the importance of teamwork. Logical teams are formed to deal with the work process and to ensure that the subprocesses interface with one another logically (similar to the tasks in the workflow). The personnel team is responsible for assigning tasks to roles. The virtual team is formed to assist the personnel team only when conflicts need to be resolved or missions need to be achieved. The technological team manages the quality of products. The outer ring for both wheels functions to implement the CE. In the product and process organisation wheel, the functions are manufacturing competitiveness, life-cycle management, process reengineering, CE definitions, system engineering, information modeling, and the whole system product realisation taxonomy. The functions for integrated product development are concurrent function deployment, total value management, development framework and architecture, decision support systems, intelligent information systems, life-cycle mechanisms, and CE implementation guidelines.

Concurrent engineering tightly links all functions involved in the product development cycle in an organisation. A successful implementing mechanism for cross-functional integration is therefore very important. Fleischer and Liker (1997) modified the five coordinating mechanisms proposed by Henry Mintzberg (1983) to concurrent engineering to improve cross-functional integration. The mechanisms are (1) direct supervision through the appropriate design of organisation architecture and project management; (2) mutual adjustment through various cross-functional teams; (3) the standardisation of design and performance metrics; (4) the standardisation of work processes, such as operational procedure, planning and scheduling systems, monitoring systems, and development process tools; and (5) the standardisation of worker skills.

that some functionalities of both the MRP II of manufacturing industries and the AIS of service industries have overlapped in some degree.

In the mid-1980s the new integrated system, called computer-integrated manufacturing (CIM), was proposed by CASA to accomplish functions such as marketing and sales, engineering, R&D, quality assurance, warehousing and distribution, shipping and receiving goods, finance and accounting control, information systems, human resources, customer service, and manufacturing material management. The architecture was again represented by SME as an enterprise wheel in 1993 (Rehg, 1994). This architecture integrates both the MRP II and AIS and beyond by introducing inventory management and sales management, financial functions, and human resources to MRP II manufacturing and engineering functions to AIS. Enterprise software such as MAPIC/DB from IBM was one of the pioneers in this area.

However, as implied by its name, the core of CIM is in manufacturing; a fact that does not attract enough attention from top executives. This causes some problems, especially when integration obstacles are encountered. Few successful cases in CIM adoption were reported during that period. However, another integration approach blazed the trail in the 1990s. It is called enterprise resources planning (ERP), which compiles similar but fewer functions than CIM. The driving force of ERP is in financial functions, the most interesting function in the enterprise system to top executives. The successful implementation of ERP from companies such as ASP, BAAN, PeopleSoft, Oracle, and J.D. Edwards has opened a large market for the enterprise system.

However, an integrated enterprise resource planning system does not provide enough competitive advantage to companies. Therefore, strategies such as linking the ERP system to electronic commerce to sell products to consumers, to suppliers to provide supply chain partnerships, to customers to provide customer relationship services, to employees to share so as to provide employee management, and to distribution centres to provide consolidated logistics service have been adopted. The outreach of ERP has created a new phenomenon, a development from an integrated intra-organisational system into an interorganisational system called EERP, or the enhanced ERP.

As will be observed from this history, the successful adoption of collaborative commerce should be business driven rather than manufacturing driven. Fortunately, collaborative commerce, as part of its name implies, has built upon the current technologies such as e-commerce, mobile commerce, ERP, and the supply chain. This provides the better ground for nourishing its growth.

Technology Infrastructure

At the time that many system and software vendors are advocating XML and Java, the need for sharing information across platforms is apparent. However, other than these two programming languages, there are three key system integration infrastructures that should be introduced to implement collaborative commerce. They are STEP, CORBA, and RosettaNet.

STEP

The standard for the exchange of product model data (STEP) is an international standard product data standard (ISO 10303) for product data exchange. The standard supports various product data formats (like engineering, manufacturing, and supporting data) throughout the life cycle of a product for many major industries, including automotive, electronics, aerospace, plant engineering, and civil engineering. For example, a CAD file of an engineering drawing with a proprietary format can be converted into a STEP format before sharing it with other companies that use proprietary CAD formats.

STEP comprises many industry-specific application protocols (APs). The APs are written in a product modelling language, called EXPRESS (ISO 10303:11), to model the necessary features in conformance with specific industry requirements. These include, for instance, AP203 for configuration-controlled design, AP207 for sheet metal die planning and design, AP210 for electronic assembly and interconnection packaging design, AP212 for electro-technical design and installation, AP224 for mechanical parts definition for production planning using machining features, AP225 for building elements using explicit shape representation, and so on. The exchanged message using a file-based exchange format is based on ISO 10303:21, in which Part 21 of the EXPRESS exchange format is used to encode the message. The numbering of the parts of this international standard reflects its structure (<http://www.npd-solutions.com/step.html>):

- Parts 11 to 13 specify the descriptive methods,
- Parts 21 to 26 specify the implementation methods,
- Parts 31 to 35 specify the conformance testing methodology and framework,
- Parts 41 to 49 specify the integrated generic resources,
- Parts 101 to 106 specify the integrated application resources,
- Parts 201 to 233 specify the application protocols,

- Parts 301 to 332 specify the abstract test suites,
- Parts 501 to 518 specify the application's interpreted constructs.

Moreover, STEP not only provides modelling methods to depict static features of product data but also provides accessing methods for placing simple queries directly on the product data model conforming to AP. The query language Standard Data Access Interface (SDAI) was proposed as a functional interface for application software to access and manipulate the STEP data model, just like SQL in terms of a database.

CORBA

The Common Object Request Broker Architecture (CORBA) is one of the earliest efforts to integrate an enterprise using object-oriented technologies. The CORBA 1.0 specification was proposed by the Object Management Group (OMG) in 1991 and a distributed object-based computing facility was adopted. The version was updated in 1993, where the Object Management Architecture (OMA) was introduced to provide CORBA services. In the version of CORBA2 (August 1996), the Internet Inter-ORB Protocol (IIOP) was proposed to improve its interoperability. Today, the CORBA3 specification has enabled enterprises to use it through vertical domain integration, such as financial, medical, and telecommunication, with either CORBA or non-CORBA infrastructure.

Being similar to Microsoft's DCOM, a distributed version of the Component Object Model (COM), CORBA provides distributed middleware to link services (such as events, directories, naming, and security) with various operating systems (like UNIX, OS/2, and NT). The middleware services are mainly supported by an Object Request Broker (ORB) and Interface Definition Language (IDL). The IDL provides interface services where the information about the interfaces is stored in the interface repository for runtime support. This is done by compiling the IDL using a binding-compliant language to generate static client-side stubs. The client can then call on the stubs to request the service. On the other hand, the ORB is the core component in CORBA. An ORB is a communication infrastructure to support communication between clients and servers. It is similar to human arteries, which transmit oxygen (service stubs). Through the services of IDL and ORB, CORBA can be used to integrate functions across heterogeneous platforms and back-end enterprise system collaborative commerce integration.

RosettaNet

The most well-integrated technology that is ready for collaborative commerce must be RosettaNet, a nonprofit consortium of more than 400 leading information technology (IT), electronic components (EC), semiconductor manufacturing (SM), and solution provider (SP) companies (<http://xml.coverages.org/rosettanet.html>). RosettaNet is named after the Rosetta stone, in which three different languages are carved and which symbolizes the communication needs among people with different cultures and different languages. The consortium therefore aims at building standards for different industries and is perfectly suitable for adoption by electronic business.

RosettaNet tries to simulate human conversation. That is, when a human wants to communicate with business partner regarding a specific business process, he/she can use a medium such as a telephone. The message must follow the grammatical rules agreed in advance, so that the other party can understand the dialogue. In fact, grammar is the system of the rules of words, and words are a collection of alphabets. Corresponding with the layers of human-to-human business conversation, the organisation uses the same ingredients to communicate with business partners. For example, in an e-business scenario, the e-business process is done through the e-commerce application, while the dialogue is actually made by the Partner Interface Processes (PIPs) standard of RosettaNet.

The PIP follows frameworks and the frameworks are the collection of dictionaries. It is no surprise that XML is considered the basic alphabet for the e-business conversation. In partner-to-partner e-business exchange layers, RosettaNet focuses on four things: the dictionary, the framework, the PIP, and the e-business process. The Rosetta dictionary defines the fundamental business data entities for business partners to define products and services. The framework, called the RosettaNet Implementation Framework (RNIF), includes some fundamental specifications for PIP communication. For example, RNIF 2.0 (<http://www.rosettanet.org/rosettanet/doc>) defines packaging (such as Multipurpose Internet Mail Extensions and Secure Multipurpose Internet Mail Extensions v2, among others), protocol stack (such as Hypertext Transfer Protocol over SSL, Simple Mail Transfer Protocol, File Transfer Protocol, and Block Extensible Exchange Protocol, among others), security (the specifications for authentication, authorisation, and encryption non-repudiation), and confidentiality (or privacy).

At the centre of the RosettaNet are the PIPs, which are grouped into seven different core business clusters: partner product and service review, product information, order management, inventory management, marketing information management, service and support, and manufacturing. Each cluster is further

broken down into segments. For example, one segment of the order management cluster is a “quote & order” entry. The necessary PIPs for business requirements are identified in each segment. Through the efforts of RosettaNet, collaborative commerce becomes feasible in the e-business environment because of the readiness with which it is prepared for business strategy, infrastructure, and business process application development.

Conclusions

Application platforms have improved in the last decades together with the implementation of enterprise systems. Previously an MRP system sharing information with a department a LAN setting was considered suitable. Then MRP II moved the focus from intra-departmental integration to interdepartmental integration. At that time, the single LAN moved to multi-LANs and WAN. The Internet has become the conveyer of information to almost everywhere in the world. At the same time, the system infrastructure also evolves from peer-to-peer linkage to client-server architecture and eventually becomes a three-tier architecture. This evolution supports the growth of enterprises from regional enterprises to global enterprises, which grows collaborative commerce itself.

To provide Internet access, most the commercial enterprise systems moved to the Internet-based ERP in the late 1990s. Nowadays, new generations of telecommunication technology, such as the current 3G technology and the anticipated 4G technologies, integrate the wire or wireless Internet with the wireless telecommunication network. This allows the business process to be executed truly anywhere and anytime. Will the new generations of telecommunication technology change the implementation of enterprise systems? Or, more precisely, will the high-speed wireless transmission change the applications of the enterprise system? Collaborative commerce no double will be one of the business models if that ever happens. But the types of collaboration may be present in many different formats. To accomplish a collaborative vision of commerce, several factors need to be considered to enable such collaboration.

- (1) *Better relationship management.* Since the collaborative commerce business model allows multiple organisations to weave a collaborative network, each collaborator should have the ability to manage the resulting dynamic business relationship. This is especially true when the collaborative community is expanded to a cyberspace marketplace.
- (2) *Better business process integration.* Collaborative commerce represents the most efficient way of doing business, where enterprises unwrap their core and competitive business functions to their collaborative partners. The

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commitment is risky but highly rewarded. The migration to collaborative commerce is equivalent to changing the business relationship from independent units to mutually dependent ones. As a result the business process of each collaborator should be understood by every partner. The business process may also need to be decomposed into smaller components so that the integration and collaboration between collaborators become possible. Moreover, the degree of concurrent operations can also be improved if the tasks can be divided into disjoint subtasks. The success of seamless collaboration can therefore be achieved by harmonizing all the business processes in the network.

- (3) *Better knowledge and information sharing.* Since the business processes are contributed to over distributed and heterogeneous networks, it is important to have a superior information infrastructure to allow the information and knowledge to be shared during the processes such as product development. Also, the better sharing of information is rewarded with better access control of the organisational data. Although sharing information is encouraged, it is not difficult to understand that all companies have their own proprietary knowledge, which is not intended to be shared with collaborators, even in the closest relationships. The company may also want to share some general information with specific partners at certain times for certain projects.
- (4) *Better collaborative culture.* Collaborative commerce brings the most talented workers together to develop products to meet consumer demands. Since the workers come from different organisations, they are influenced by different organisational cultures as well as being encouraged by different incentive schemes. Therefore, the successful building of a collaborative atmosphere across organisations determines the success of collaborative commerce.

In conclusion, an integrated and intelligent system supporting knowledge sharing and collaboration can help companies to distinguish themselves from their competitors. There are many application areas and issues that need to be considered in collaborative commerce. These topics include areas such as the management of a business infrastructure, capital markets and the virtual economy, improvement of data quality, support of decisions and group systems, enterprise strategies, entrepreneurship and creativity, enterprise process management, innovation and product development, Internet law and compliance, Internet security and privacy issues, and knowledge management business ethics. They will be addressed in the following chapters.

Endnotes

- ¹ The short version of this chapter was presented at the International Conference on Electronic Business (ICEB2003) in Singapore.

Chapter II

Electronic Collaboration, Communication and Cooperation: A Taxonomy and a Prototype

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Abstract

This chapter investigates the subject of e-collaboration and proposes a meta-taxonomy that classifies the existing taxonomies of collaborative systems found in the literature. It also points out the three dimensions in e-collaboration: communication, cooperation, and coordination. The most commonly encountered functions of collaborative systems are identified through an extensive review of commercial and research products. The functions and the systems are classified with relevance to the communication, cooperation, and coordination dimensions. We find that although all three dimensions of collaboration are necessary for the successful completion of work, there is a lack of an integrated system enabling all of them. Consequently we present the C-CUBED system, which attempts to support all three collaboration dimensions.

Introduction

E-collaboration and collaborative systems bring geographically dispersed groups together, enhancing communication, coordination, and cooperation. This results in tremendous time and cost saving, greatly decreased travel requirements, faster and better decision making, and improved communication flow throughout the organization.

Broadly defined, the term *electronic collaboration* encompasses the support of communication and coordination of two or more people through the use of software programs in an effort to fulfil an assignment or solve a problem together (Borenstein, 1992; Schooler, 1996).

Researchers have identified at an early stage the need for providing means for classification of the systems supporting e-collaboration. Therefore classification efforts have existed since the early 80s, and their number continues to grow.

This chapter performs a review of the research field of online collaboration and provides a meta-taxonomy of the classification schemes of collaborative systems in the literature. In addition we present a prototype classification and identify the need for a system that would support in an integrated way the communication, cooperation, and coordination dimensions of e-collaboration. Finally, we suggest the functional and technical architecture of a prototype system developed to address this need through the access and management of shared artefacts and offering, at the same time, coordination capabilities through the automation of business processes with the use of workflow management technologies.

The chapter is organized in the following manner: the next section gives an overview of previous literature concerning taxonomies and classifications of collaborative applications. Then, the chapter discusses some of the most common collaboration functions, while the three dimensions of e-collaboration along with their basic characteristics are defined. The chapter then introduces the proposed taxonomy of collaborative systems, and is followed with a presentation of the results of our research on the market of e-collaboration, giving information about the examined systems and also correlating the systems with the identified collaboration functions. In the same section we also identify the lack of a system supporting in an integrated manner all three collaboration dimensions. Next, the chapter presents the technical and functional architecture of a prototype application, as well as a usage scenario of this system applied in the tendering/bidding process. Finally, the chapter discusses our conclusions and indicates future research issues.

Taxonomies of Collaborative Systems in the Literature

A classification criterion of collaborative systems defines a dimension of these systems or a set of possible values that a characteristic of these systems can assume (Antillanca & Fuller, 1999).

Criteria are usually presented in taxonomies. A taxonomy creates a relationship between the classification criteria and therefore can be considered as a multidimensional space, where each criterion corresponds to a dimension (Reinhard, Schweitzer, Volksen, & Weber, 1994).

Where collaborative applications are concerned, taxonomies are especially useful, mostly when initial requirement decisions must be made. Also, taxonomies provide ways of comparison of the existing applications and give the possibility to classify new applications in existing taxonomies. In case of insufficiency of the existing taxonomies, the fuel is given for creating new ones. Finally it is easy to identify the areas with inadequate software coverage and provide new, enhanced software products.

A first approach to provide a taxonomy of collaborative systems is to distinguish them by *when* and *where* the interaction takes place (time/space taxonomy; see DeSanctis & Gallupe, 1987; Ellis, Gibbs, & Rein, 1991; Johansen, 1988). In this context, two primary dimensions are identified (see *Table 1*).

Table 1. Time/Space Classification

	Same Time	Different Time
Same Space	<i>Face-to-face interaction</i> Conference Tables Public screens Tools for voting and exchanging of ideas	<i>Tasks that range over time</i> Spaces that belong to groups Screens accessed by groups <i>Tasks with different time schedules</i> Project management
Different Time	<i>Remote, real-time interactions</i> Chat systems Shared access to applications Notification system for a prospective collaboration Use of multimedia	<i>Communication & Coordination</i> E-mail Electronic bulletin boards Asynchronous conferences Workflow management systems Document management Programming

In the horizontal dimension we order collaborative tools by the location of participants: they can be either at the same place (also referred to as colocated) or at different places (remote). Similarly, the vertical dimension makes the distinction whether the interaction happens at the same time (synchronous) or at different times (asynchronous). These dimensions provide four communication scenarios: synchronous, colocated; asynchronous, colocated; synchronous, remote; and asynchronous, remote.

Grudin (1994) also provides a classification of collaborative systems in terms of *time* and *space*. Time and space settings in collaborative software can be classified as *same*, *different but predictable*, and *different and unpredictable*. Accordingly, nine different categories of collaborative systems emerge (see *Table 2*).

A review of the literature reveals several other classifications of systems that support group work. DeSanctis and Gallupe (1987) discuss a taxonomy based on *group size* (smaller, larger) and *task type* (planning, creativity, intellectual, preference, cognitive, conflict, mixed motive).

Kraemer and King (1988) provide a classification of group decision support systems (GDSSs). GDSSs are categorized with regards to the hardware they need, the software required, the people they involve, and the organizational data needed.

Apart from the space/time taxonomy, Ellis et al. (1991) describe a taxonomy based on *application-functionality*, and Coleman (1995) also provides 12 categories of collaborative systems in the same domain.

Jarczyk, Loffler, and Volkson (1992) developed a taxonomy to characterize collaborative systems where five major classes of criteria are defined: *functional*, *technical*, *application*, *usability* and *ergonomics*, and *scalability*.

Table 2. Collaborative System Categories

	Same Time	Different Time Predictable	Different Time Unpredictable
Same Space	Electronic meetings	Work with different schedules	Spaces belonging to groups
Different Space Predictable	Whiteboards Conferences with the use of multimedia	Voice mail	Collaborative writing
Different Space Unpredictable	Broadcast seminars	Asynchronous conferences	Workflow Management

Adapted from Grudin (1994)

The functional criteria describe the features of systems; the technical characterize the platform, the environment, and the system architecture; the application criteria help to define the application domain; usability and ergonomics are important for the acceptance of a tool; and, finally, orthogonality and scalability are meta-criteria that focus on the flexibility of the system with respect to the other criteria.

Mentzas (1993) classifies collaborative software based on four major criteria: *coordination model characteristics*, *type of processing*, *decision support issues*, and *organizational environment*.

McGrath and Hollingshead (1994) deal with a task framework, where group tasks are classified in four quadrants. Each quadrant is characterized by a general performance process (action of a group): *generate* (alternatives), *choose* (alternatives), *negotiate*, and *execute*. The quadrants are then subdivided into two types of tasks each, and as a result eight different types of tasks arise. The task circumplex is a two-dimensional representation. The horizontal dimension shows a contrast between behavioural or action tasks to the right and conceptual or intellectual tasks to the left. The vertical dimension reflects a contrast between cooperation or facilitative compliance at the top and conflict at the bottom.

Malone and Crowston (1994) define a taxonomy based on a collaboration/coordination model. According to their framework, four levels of processes are defined: *collaboration/coordination*, *group decision-making*, *communication among the collaborators* and *perception of common artefacts*.

Teufel, Sauter, Mühlherr, and Bauknecht (1995), in an effort to categorize the collaboration systems, distinguish three possibilities of electronic support for collaborative processes: *communication support*, *cooperation support*, and *coordination support*. The various systems are placed in a triangle according to the basic functionality of each one and in relation to the three possibilities for electronic support. The systems are further grouped in four categories: communication systems, shared information spaces, workflow management, and work-group computing.

In the groupware bible of Lotus Development Corporation (1996) are identified three classes of software supporting online collaboration: *communication systems*, *collaboration systems*, and *coordination systems*. Communication systems are means that passively transmit information. The complexity of those systems ranges from simple tools supporting same time, same place, one-to-one interaction to sophisticated software capable of handling same as well as different time and space situations including a large number of participants. Collaboration systems are common workspaces, which contribute to the diminution of time and space constraints. Examples of such systems are electronic conferencing systems and shared databases. Finally, coordination systems

Table 3. Collaboration Dimensions in the Literature

Authors		Classification Criteria												
		De Sanctis & Gallupe (1987)	Kraemer & King (1988)	Johansen (1991)	Ellis, Gibbs, Rein (1991)	Volksen (1992)	Mentzas (1993)	McGrath & Hollingshead (1993)	Grudin (1994)	Malone & Crowston (1994)	Teufel et al. (1995)	Coleman (1995)	Lotus Corporation (1996)	Ellis (2000)
Time/Space				*	*		*		*					
Application					*	*					*	*	*	*
Group Issues	Group Size	*				*								
	Group Characteristics		*											
	Types of Group Tasks	*						*	*					
Technical	Hardware		*			*								
	Software		*			*	*							*
	Scalability					*								
Other	Type of Interaction				*	*	*							
	Usability/Ergonomics					*								

- *Electronic Mail*: The most common and widespread communication tool. It allows wide contact over the Internet and its primary use is for text messages, normally relatively brief. Often the messages are accompanied by file attachments.
- *Chat*: Real-time text talk where messages appear on both users' screens. Usually, a split screen is used, where the local typing appears in one part and the remote in the other. There is no particular subject set and it does not scale to more than a very few users.
- *Bulletin Board*: A message board where a conversation can be carried on over time. The user can leave a message for someone, they can answer it, and the initiator can respond back to them later.
- *Whiteboard*: Whiteboards allow two or more people to view and draw on a shared drawing surface. This may be used for discussing or describing

combine structured communication and collaboration actions and also support informal conversations.

Ellis (2000) provides a categorization of collaborative systems according to the underlying technology. Thus, four aspects are determined: *keepers*, *coordinators*, *communicators*, and *team agents*. Briefly, the first aspect, keepers, groups all functionality related to storage and access to shared data. The second aspect, coordinators, is related to the ordering and synchronization of individual activities that make up the whole process. The third aspect, communicators, groups all functionality related to unconstrained and explicit communication among the participants. Finally, the fourth aspect, team agents, refers to intelligent or semi-intelligent software components that perform specialized functions and help the dynamics of a group.

Meier (2002) distinguishes three dimensions in the area of collaboration and cooperative work: *coordination*, *communication*, and *common ground*. Collaboration support systems are also classified based on whether they provide *synchronous* or *asynchronous communication and collaboration support* and whether they address the needs of *individuals*, *teams*, or *organizations/networks/communities*.

Table 3 sums up all the above references in the literature. The authors are presented with regards to the classification dimensions they have dealt with. Four major dimensions are identified: time/space, application, group issues, and technical criteria.

Several sub-dimensions are also provided. Under group issues, for instance, we can distinguish group size (smaller-larger groups), characteristics of the group, and types of group tasks. Group characteristics include the existence or no of a facilitator and the group composition, which in turn determines the cohesiveness of the group and the relationships between the members. There are eight types of group tasks: planning, creativity, intellectual, decision making, cognitive conflict, mixed-motive, competitive, and performance/psychomotor tasks.

Technical criteria include hardware, software, and scalability. The mode of interaction among users (implicit-explicit, formal-informal, communication, collaboration, perception of common objects) and the usability/ergonomics criteria are equally important.

Functions of Collaborative Systems

The following paragraphs briefly describe the typical functions of tools supporting collaborative work over the Web, as those resulted from an extended survey on a large number of systems and the study of literature taxonomies.

objects which are difficult to verbalise. Most shared whiteboards are designed for informal conversation, but they may also serve structured communications or more sophisticated drawing tasks, such as collaborative graphic design, publishing, or engineering applications. Shared whiteboards can indicate where each person is drawing or pointing by showing telepointers, which are colour-coded or labelled to identify each person.

- *File and Document Sharing*: This function includes the possibility of viewing and editing shared files. Files are stored in a central server and users can work on them, either using their local applications or the tool's functionality. Occasionally, there is the possibility for version control, search, electronic signing, and access control.
- *Synchronous Work on Files*: Files can be edited simultaneously by a number of users, either on each other's screen or on a whiteboard.
- *Screen Sharing*: Both people have the same view of the screen, and possibly the remote user can take control of the other user's system. Screen sharing can mean that either only the view of the screen is shared (essentially a graphic representation of one screen is passed to the other screen) or applications can be shared, in which case events from the remote keyboard and mouse are used to drive the local input and pointer.
- *Presentation Capability*: Users can conduct presentations, i.e., show and annotate PowerPoint slides.
- *Task List*: Lists of actions to be performed, pending activities, unresolved problems, and scheduled meetings are kept, and the user is notified of new items in the list.
- *Meeting Scheduling Tools*: Meeting scheduling tools include creating meeting agendas and lists of issues or using calendars for organizing meetings.
- *Electronic Calendars*: The electronic calendar supports the enhanced collaboration of group members, providing common access to meeting schedules. The members not only have the possibility to register information about their personal appointments but also have access to similar information involving other users. In several occasions users receive notifications about future scheduled meetings.
- *Workflow Management*: A workflow is defined as a collection of tasks organized in such a way to form a business process. The components of the business process, according to the Workflow Management Coalition (1999) model, are presented in *Figure 1*.

A workflow management system is a system that defines, creates, and manages the execution of workflows, using software that “runs” in one or more workflow engines.

A workflow life-cycle is fragmented in different parts that can be usually grouped in two phases: the workflow design phase (build time) and the workflow execution phase (runtime or enactment).

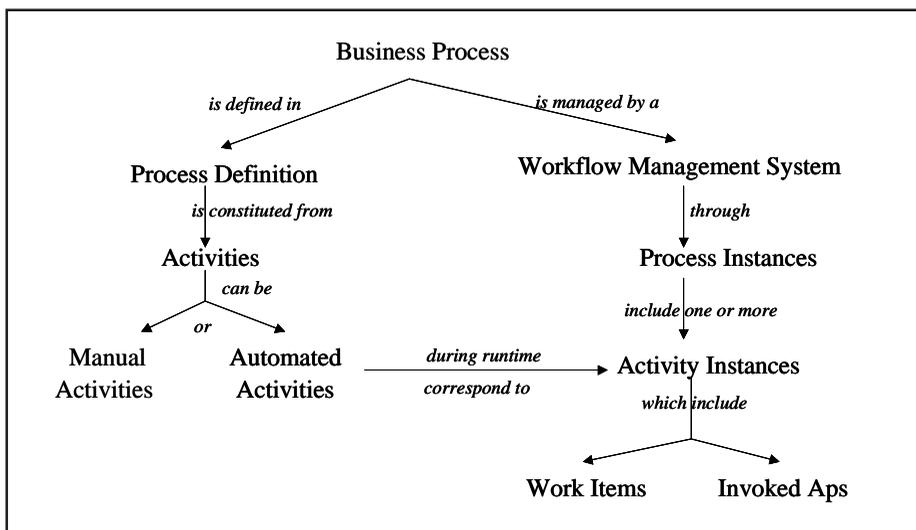
The build-time functions include the definition and modelling of the workflow process and its activities. These functions result in the definition of a business process, using the computer. More explicitly, during the build time, the business process is translated from its real-world form to a typical, managed-by-a-computer form, using one or more system analysis and modelling techniques. This process form can be further divided in sub-activities/tasks.

An activity is a collection of events, a sequence of logically connected functions that can be executed by an entity that is a person holding a specific role (actor), a system (processing entity), or a combination of the above.

A workflow, though, not only defines a collection of tasks but also their sequence, the conditions that govern the task execution, their synchronization, and the dataflow.

At runtime, the process definition is translated and executed by the workflow engine, which is responsible for the creation and control of operational instances, the programming of the various activities, and the use of the appropriate human and computer resources.

Figure 1. Business Process Components



During runtime, each participant has access to a task list corresponding to work items. This task list can be edited according to the work items' priority. As a result, work items are performed either instantly or at a later stage.

Collaboration Dimensions

Business processes have constituted for several years point of interest and object of research for the development of software systems to support them. Lately the emphasis is given on the collaborative nature of business processes that take place in organizations and are performed by groups.

The globalisation of markets and the increased competition intensify the need for business processes that evolve quicker and are of lower cost for the organization. Moreover, the development of new forms of organizations, like the virtual consortia, demands faster and more flexible responses to the challenges of the dynamically evolving markets.

Specialized groups of people created by members of different companies, collaborating mostly on a temporary basis, should work together in order to generate the requested results. Electronic collaboration becomes common practice nowadays.

Various researchers have already pointed out the three basic dimensions of e-collaboration: communication, cooperation, and coordination (Lotus, 1996; Teufel et al., 1995). In the next paragraphs we analyse the basic features and identify the most usual functions of IT platforms that electronically support each of the three dimensions.

Communication

The term communication includes basic information exchange among the parties involved in a collaborative situation. Emphasis is given on the explicit interaction between two or more people, either in the context of a discussion or during the exchange of an electronic message.

Communication processes do not usually have a structure or specific sequence of steps. They can take place either randomly or on a predefined schedule. There are possibilities for bilateral (one-to-one) or multilateral (one-to-many, many-to-many) communication and real-time or asynchronous interaction.

Communication support has been the primary focus of many software systems. The simple, text-based communication with the use of electronic mail has now

been enhanced with multimedia (voice contact and electronic conferences with the use of video).

The software for electronic mail is still the most common and widely used. There is need for low-cost software offering speed and easiness of application and use.

Cooperation

Under the term cooperation we group the possibilities for work on shared documents and files of various formats. In essence, cooperation is about the actual collaboration of groups, aiming at the generation of artefacts.

The interaction in this case is implicit and takes place through the reference on the shared artefact, it can occur at the same time or asynchronously, and the use of multimedia is usually not included. Group work is stored in repositories and is accessible by all interested parties according to their access rights. The user interface is usually simple and no special programming knowledge is requested.

Coordination

The concept of coordination focuses on the programming and scheduling of activities performed by the involved actors in a collaboration process.

Simple coordination capabilities offer the electronic calendaring tools. Electronic calendars can be used either for personal or for group scheduling.

Also, elementary coordination is accomplished when interfacing with some electronic conferencing products and electronic meeting and electronic workspace systems through the use of task lists and meeting scheduling tools.

Basically, though, the dimension of coordination is supported by workflow management systems. These systems offer assistance for strictly structured actions that happen at a specific order as well as for semi-structured processes that require intellectual work and whose parts are insufficiently defined and changeable. In both cases, interaction is implicit and of different time and space.

Proposed Taxonomy

The functions described in section two can be classified in relation to the time and space dimensions (see *Table 4*). As one can conclude by studying *Table 4*, file and document sharing is mostly remote and asynchronous, while real-time

Table 4. Temporal and Spatial Dimensions of Collaborative Functions

Function	Temporal Dimension		Spatial Dimension	
	Synchronous	Asynchronous	Co-Located	Remote
E-mail		■		■
Chat	■		■	■
Bulletin Board		■		■
Discussion	■	■	■	■
Whiteboard	■		■	■
File & Document sharing		■		■
Synchronous work on files	■		■	■
Screen Sharing	■		■	■
Presentation Capability	■	■	■	■
Task list		■		■
Meeting scheduling tools		■		■
Electronic Calendar		■		■
Workflow Management		■		■

cooperation takes place in the case of synchronous work on files and screen sharing, where both dimensions of space are also included. Presentations can be conducted either synchronously or asynchronously, and interacting users can be either in remote locations or at the same place. Finally, asynchronous and remote are the functions of task lists, meeting scheduling, electronic calendars, and workflow management.

The proposed taxonomy is about classifying collaboration functions with regards to the collaboration dimensions. As a result the typical functions of each dimension are easily identified.

In the context of our taxonomy, we create *Table 5*, where all functions are presented according to the degree of communication, cooperation, and coordination they support. We consider three levels of support: low (*), medium (**), and high (***)

Table 5. Functions and Collaborative Dimensions

Collaboration Dimensions	Communication	Cooperation	Coordination
Functions			
E-mail	**	*	*
Chat	***	*	*
Bulletin Board	**	*	*
Synchronous discussion	***	*	*
Asynchronous discussion	**	*	*
Whiteboard	**	***	*
File management	*	**	*
Synchronous work on files	**	***	*
Screen sharing	**	***	*
Presentation capability	**	***	*
Task list	*	*	**
Meeting scheduling tools	**	*	**
Electronic Calendar	*	*	**
Workflow Management	**	**	***
	***	High support of the dimension	
	**	Medium support of the dimension	
	*	Low support of the dimension	

We make the following acknowledgments: we consider the real-time interaction as offering a high possibility of communication. The support for cooperation is considered high with functions involving shared, real-time editing of files, and, finally, workflow management corresponds to the highest level of coordination. *Table 5* is created taking also into consideration the time/space classification of *Table 4*.

Based on *Table 5*, we can identify the functions that are typical for each dimension. We usually select the functions with “***” at the corresponding column. In some cases, as is electronic mail, the incorporation of the function in a dimension is obvious, even with “**” at the required column.

Table 6 describes briefly the three collaboration dimensions, including a short definition and a list of the basic functions of each dimension.

Systems Supporting e-Collaboration

In the context of our research, we have examined 60 products, either commercially available or research prototypes, which satisfy in some respect the user requirements for communication, cooperation, and coordination. *Table 7* provides company and URL information for the examined systems.

Table 6. Brief Description of Collaborative Dimensions

Collaboration Dimensions	Definition	Functions
Communication	Explicit interaction of two or more people aiming at the exchange of information of any kind	E-mail
		Chat
Cooperation	Implicit interaction taking place through reference to a common artefact	File & Document Sharing
		Synchronous work on files
		Whiteboard
		Screen sharing
Coordination	Programming and settlement of activities performed by the parties involved in a collaboration process	Presentation capability
		Task list
		Meeting scheduling tools
		Electronic Calendars
		Workflow Management

Table 7a. General Information About the Systems

Tools	Company	URL
CommonSpace	Sixth Floor Media, USA	http://www.sixthfloor.com
DocuTouch	DocuTouch Corporation, USA	http://www.docutouch.com
Documentum	Documentum, USA	http://www.documentum.com
TeamNow	TeamNow, Denmark	http://www.teamnow.com
CentraNow	Centra, USA	http://www.centranow.com
Consensus@nyWARE	SoftBicycle, USA	http://www.softbicycle.com
CuSeeMe Conference Server	CuSeeMe Networks, USA	http://www.cuseeme.com
DOLPHIN	GMD, Germany	http://www.darmstadt.gmd.de/
Evoke Collaboration	Evoke Communications, USA	http://www.evoke.com
Facilitate.com	Facilitate.com, USA	http://www.facilitate.com
Grouputer	Stepup Systems, Australia	http://www.stepup.com.au/
HelpMeeting	HelpMeeting LLC, USA	http://www.helpmeeting.com
MeetingRoom	GroupSystems.com, USA	http://www.ventana.com
PlaceWare	PlaceWare, USA	http://www.placeware.com
Web-4M	JDH Technologies, USA	http://www.jdhtech.com
aspSmartForum	Advantys, France	http://www.aspsmart.com
Instant!TEAMROOM	Lotus, USA	http://www.lotus.com
Intranets	Intranets.com, USA	http://www.intanets.com
Project place	Projectplace International AB, Stockholm	http://www.projectplace.co.uk
TeamTalk	Trax Softworks, USA	http://www.webcom.com/
VJungle	Vjungle, USA	http://www.vjungle.com
WebBoard	O'Reilly Software, USA	http://www.webboard.oreilly.com
MeetingPlace	Latitude, USA	http://www.latitude.com
NetMeeting	Microsoft, USA	http://www.microsoft.com
PictureTalk	Pixion, USA	http://www.pixion.com
Sametime	Lotus, USA	http://www.lotus.com
BSCW	GMD, Germany	http://bscw.gmd.de
Business Manager	Info Parc, Austria	http://www.infoparc.com
Caucus	Caucus Systems, USA	http://www.caucus.com
Collab Fab	Collaboration Fabricators	http://www.collabfab.com

Table 7b. General Information About the Systems

Tools	Company	URL
CWV	Mitre, USA	http://cww.sourceforge.net
Cybozu Office 3	Cybozu, Japan	http://cybozu.com
DIVA	GMD, Germany	http://orgwis.gmd.de/projects
eRoom	eRoom Technology, UK	http://www.eroom.com
Forum	SiteScape, USA	http://www.sitescape.com/
Groove	Groove Networks, USA	http://www.groove.net
GroupPORT	GroupServe, USA	http://gp1.groupport.com
GroupWise	Novell, USA	http://www.novell.com/
HyperOffice	myWebOS.com, USA	http://www.hyperoffice.com
InfoWorkSpace	General Dynamics, USA	http://www.infoworkspace.com
Intraspect c-Business Platform	Intraspect Software, USA	http://www.intraspect.com
JointPlanning	USA	http://www.jointplanning.com
QuickPlace	Lotus, USA	http://www.lotus.com
teamOn	teamOn, USA	http://www.teamon.com
TeamWave	TeamWave Software, USA	http://www.teamwave.com
VEGA	Universities of Berne, Lausanne	http://vega.vptt.ch
CSE/Workflow	CSE Systems	http://www.csesys.co.at
FlowMark	IBM, USA	http://www.ibm.com
GFI Emailflow for Exchange/SMTP	DocMan Technologies	http://www.docmantech.com
Ultimus Workflow Suite	Ultimus	http://www.ultimus.com
ActionWorks Metro	Action Technologies, USA	http://www.actionworksmetro.com
Keyflow	IComXPress, USA	http://www.icomxpress.com
Panagon Visual WorkFlo & IDM Desktop	FileNET Corporation, USA	http://www.filenet.com
Staffware	Staffware, UK	http://www.staffware.com
TeamWARE Flow, DOLPHIN	Fujitsu, Malaysia	http://www.teamware.com
TIB/InConcert Workflow	TIBCO Software Inc.	http://www.tibco.com/products/in_concert
Domino Workflow	IBM Lotus Notes	http://www.lotus.com
FORO	SEMA Group	http://www.sema.es/sp/productos/generales.htm
AIS Workware Demonstrator	Sintef	http://www.informatics.sintef.no/projects/ais/eksternweb
ADERT _{WORKFLOW}	University of Ulm	http://www.informatik.uni-ulm.de/dbis/f&l/forschung/workflow/text-adept_e.html

Table 8a. Collaborative Systems and Their Basic Functions

Tools \ Functions	Communication				Cooperation				Coordination				
	E-mail	Chat	Bulletin Board	Discussions	File Management	Synchronous work on files	Whiteboard	Screen Sharing	Presentation Capability	Task list	Meeting Scheduling Tools	Electronic Calendars	Workflow Management
CommonSpace				•	•	•							
DocuTouch					•								
Documentum					•								
TeamNow					•	•							
CentraNow	•	•		•			•	•	•				
Consensus @nyWARE				•						•	•		
DOLPHIN					•	•	•		•		•		
CuSeeMe Conference Server											•		
Evoked Collaboration		•					•	•	•				
Facilitate.com				•							•		
Grouputer				•							•		
HelpMeeting		•				•	•	•	•		•		
MeetingRoom				•							•		
PlaceWare		•				•	•	•	•	•			
Web-4M		•		•			•		•				
aspSmartForum	•			•									
InstantTEAMROOM	•			•	•								
Intranets	•			•	•						•		
Project place				•	•					•	•		
TeamTalk				•									
wJungle	•	•											
WebBoard		•		•									
MeetingPlace				•	•								
NetMeeting		•		•			•	•					
PictureTalk								•	•				
Sametime		•		•		•	•	•					
BSCW				•	•				•				
Business Manager										•			
Caucus				•	•				•				

Table 8b. Collaborative Systems and Their Basic Functions

Tools \ Functions	Communication				Cooperation				Coordination				
	E-mail	Chat	Bulletin Board	Discussions	File Management	Synchronous work on files	Whiteboard	Screen Sharing	Presentation Capability	Task list	Meeting Scheduling Tools	Electronic Calendars	Workflow Management
Collab Fab				•	•					•			
CVW		•			•		•						
Cybozu Office 3	•		•							•			
DIVA		•	•	•	•	•	•						
eRoom				•	•								
Forum	•	•		•	•						•		
Groove		•		•			•						
GroupPORT	•			•									
GroupWise	•			•	•								
HyperOffice	•	•			•		•			•		•	
InfoWorkSpace		•		•			•	•	•				
Intraspect c-Business Platform	•												
JointPlanning	•			•						•			
QuickPlace		•		•	•								
teamOn	•		•	•							•		
TeamWave		•	•		•		•	•	•	•	•	•	
VEGA				•	•						•		
CSEWorkflow	•												•
FlowMark													•
GFI Emailflow for Exchange/SMTP	•												•
Ultimus Workflow Suite	•												•
ActionWorks Metro	•												•
Keyflow	•												•
Panagon Visual WorkFlo & IDM Desktop					•								•
Ensemble	•												•
Staffware	•												•
TeamWARE Flow, DOLPHIN	•												•
TIB/inConcertWorkflow													•
Lotus Workflow	•												•
FORO													•
AIS Workware Demonstrator													•
ADERT _{WORKFLOW}													•

Consequently, the basic functions of each system are identified and demonstrated in *Table 8*.

Based on the three collaboration dimensions and their basic functions (see *Table 6*), we derive the conclusion that the electronic support of collaboration has primarily focused on two axes: either on the coordination of business processes performed asynchronously by different actors (using, for example, a workflow management system) or on the automation of communication and cooperation for groups involved in more loose processes (i.e., electronic mail, electronic workspaces, etc.).

However, there exist several research efforts towards the integration of workflow management systems with tools supporting communication and cooperation (Agostini & De Michelis, 2000; Araujo & Borges, 2001; Bussler, 2000; Haake & Wang, 1999; Kammer & McDonald, 1999; Kreifelts, Hinrichs, & Woetzel, 1999).

In the next section, we propose a system (coded C-CUBED) that makes available to the users a common workspace, where files of different formats can be stored and edited, asynchronous discussions and real-time text talk can take place, and meetings can be conducted, facilitating decision making. At the same time users can take advantage of automated workflows that correspond to their critical business processes. The system's capabilities cover a broad spectrum of functions belonging to all three collaboration dimensions. Compared to other research approaches, our prototype does not focus on exception handling; rather, it focuses on the integration of the coordination, communication, and cooperation dimensions and targets the efficient fulfillment of predefined activities.

C-CUBED Prototype Tool

C-CUBED is a prototype tool enhancing e-collaboration through functions such as electronic mail, asynchronous and synchronous discussions, text chat, whiteboard, screen sharing, polling, and file management. The system can be used during the interaction of teams either within organizations (e.g., in the case of virtual teams working in a time- and resource-constrained project) or across organizations (e.g., in the case of a collaborative commerce project that focuses on new product development).

Functional Architecture

Our primary concept, upon which the functional as well as the technical architecture of the C-CUBED prototype is based, is the concept of the virtual “room.” The “room” is a workplace where users and computational objects are stored. The integration of the virtual room in a collaboration environment facilitates the transition from personal work to group efforts. Moreover, users of the system can move freely from synchronous to asynchronous modes of interaction.

The functional structure of a system depicts the various subsystems that make up the whole system as well as the way these subsystems interconnect. The functional design analyses the functions of the system in relation to the requirements set for it.

In this context, the C-CUBED system is structured by autonomous subsystems, as shown in *Figure 2*. Specifically there are seven discrete subsystems:

- the file management subsystem, providing functionalities for creating, editing, and exchanging files;
- the workflow management subsystem, which supports the automation of business processes;
- the communication subsystem, which, on the one hand, provides connection with databases including data of interest to the users and, on the other hand, supports the communication among users of the system;
- the administration subsystem, enabling the user to insert new users in the rooms and manage the information entered in the system;
- the help subsystem, which provides help to the end user for functional as well as technical issues;
- the user interface subsystem, which facilitates and expedites the interaction between the end user and the system; and
- the access control subsystem, which involves registration to C-CUBED and user validation before they can access any required information.

The functions for synchronous communication and cooperation include:

- a shared whiteboard;
- screen and program sharing;

- real-time text chat;
- conduction of surveys and polls;
- instant messages; and
- group awareness mechanisms.

Technical Architecture

Technically, the C-CUBED system is based on a Lotus Domino server and was developed using programming languages such as Java and JavaScript. LotusScript and Notes Formula, two languages specifically suited for creating Domino applications, were also used. The overall system architecture is shown in *Figure 3*.

The system consists of a set of databases stored on the server. Such databases include the room database, which serves as a repository of the rooms of the system; the database, where the discussion topics (Discussion Db) are stored; the databases involving the workflow definition, enactment, and management; and other databases dealing with user authentication, communication, and address books.

Figure 2. Functional Architecture of the C-CUBED Prototype

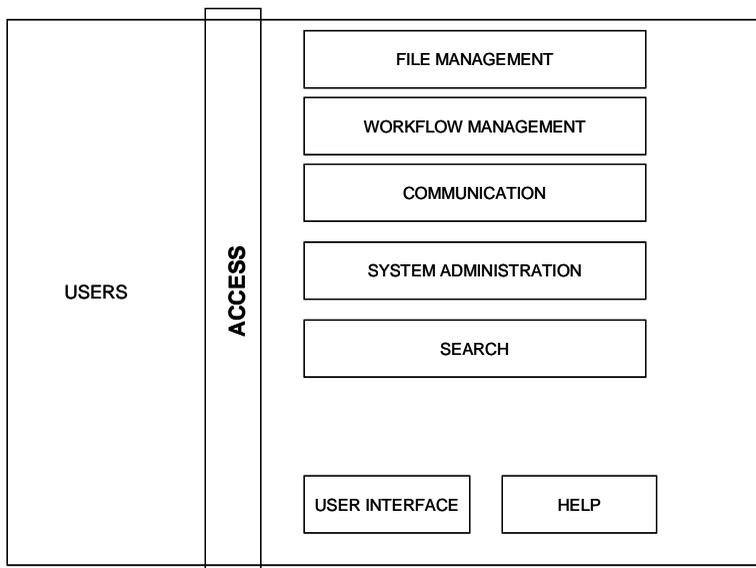
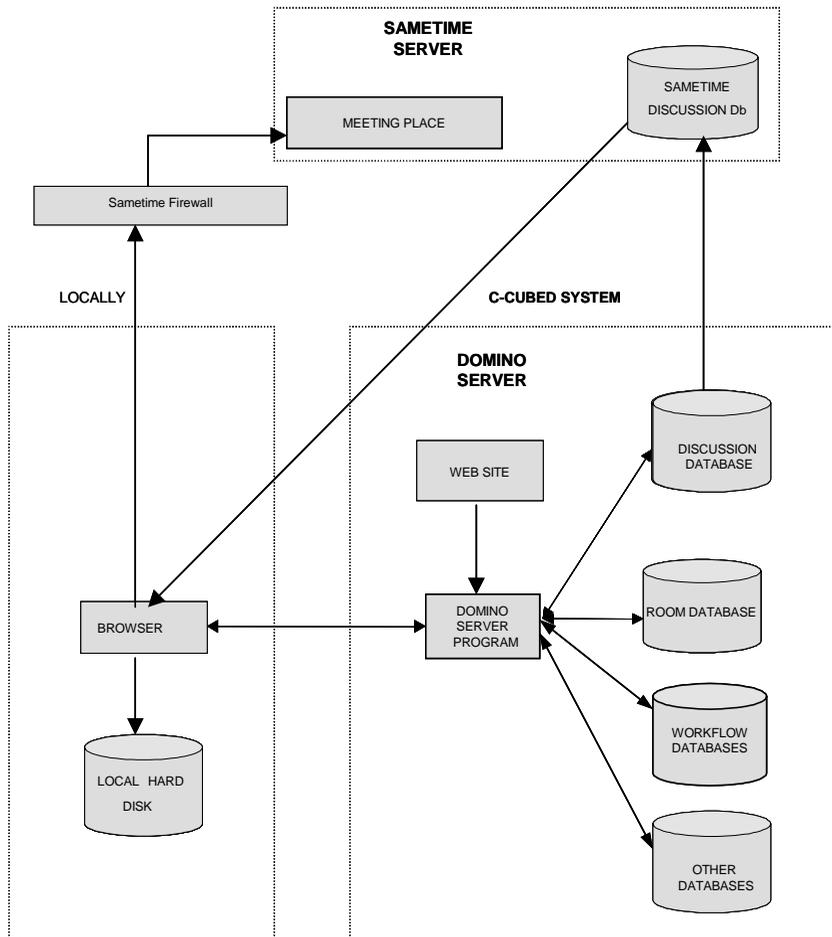


Figure 3. Technical Architecture of the C-CUBED Prototype



Synchronous communication and cooperation functions are available through connection to the Lotus Sametime server. The Sametime server is connected to the Domino server to make use of the catalogue services. Also, the database dedicated to discussion (Discussion Db) is connected to the Sametime in order to obtain the synchronous characteristics. As a result, the Sametime discussion database is created. This database combines features for asynchronous as well as synchronous discussions, group awareness, and real-time text chat capabilities.

Use Scenario

Our usage scenario examines the case of a project-centric virtual organization, made up of various companies that collaborate electronically.

In the case of project-centric business environments, as, for instance, in the construction sector, a critical business process is tendering/bidding for a new project. This process is either internal in the organization or inter-organizational. The latter case occurs in the context of the new forms of network business organizations, which are grouped under the term of “virtual consortium” and hold the following characteristics (Halaris, Kerridge, Bafoutsou, Mentzas, & Kerridge, 2001):

- they are created by organizations remotely located, whose fundamental competencies are complementary and are oriented towards the same business opportunity, and
- they use the Internet for the exchange of data and information between them.

The C-CUBED prototype can be successfully applied in all collaboration situations described in the previous paragraphs. For the purposes of the use scenario that follows, we choose the tendering/bidding process in the construction sector environment, where business opportunities are identified in calls for tenders and the formation of consortia is a common practice.

The workflow designer models the tendering/bidding process using the Lotus Workflow Architect, a tool for graphical design of business processes (see *Figure 4*), and also defines the organizational diagram of the enterprises participating in the process and the roles for the workflow automation (see *Figure 5*).

The use scenario considers that the end user is a member of an enterprise of the construction sector, wishing to bid for a contract. More specifically, the end user belongs to the bidding workgroup. The firm has already made the decision to create a virtual consortium in order to meet the requirements of the contract as far as resources and experience are concerned.

The end user is connected to C-CUBED and creates a new room, the common workspace for all members of the bidding workgroup. The goal is to create an invitation for partnership in the context of creating a virtual consortium.

Room creation is followed by the definition of the rest of the room users and the storing of files relevant to the bid and the company-recipient of the partnership

Figure 4. "Form a VC" Workflow Process

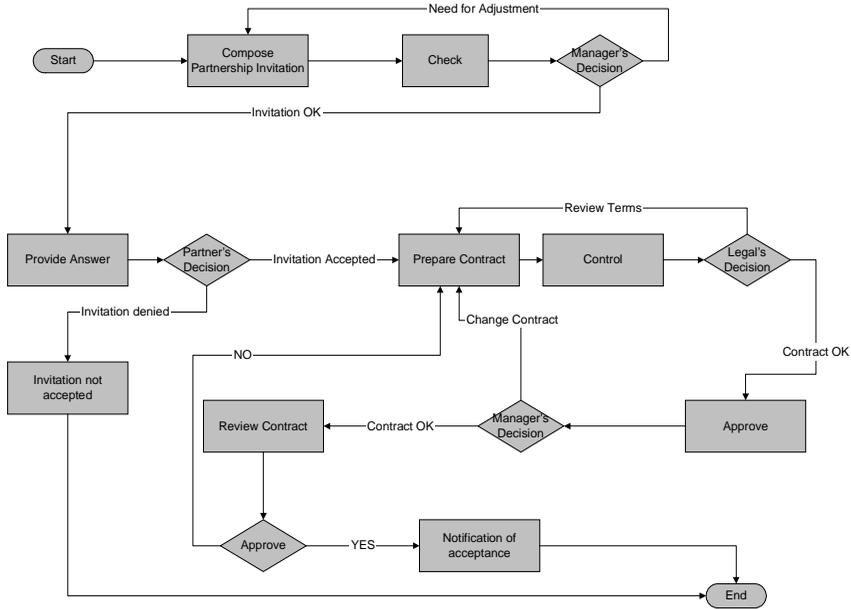


Figure 5. Organizational Database4

Department name	Members	Manager	Substitutes
Accounting	George Papavasiliou/IMU	George Papavasiliou/IMU	
Legal	Giannis Vargnadis/IMU	Giannis Vargnadis/IMU	
Public Relations	Kostas Kalentzis/IMU Gregory Mentzas/IMU	Georgia Baloutou/IMU	

Figure 6. The Room

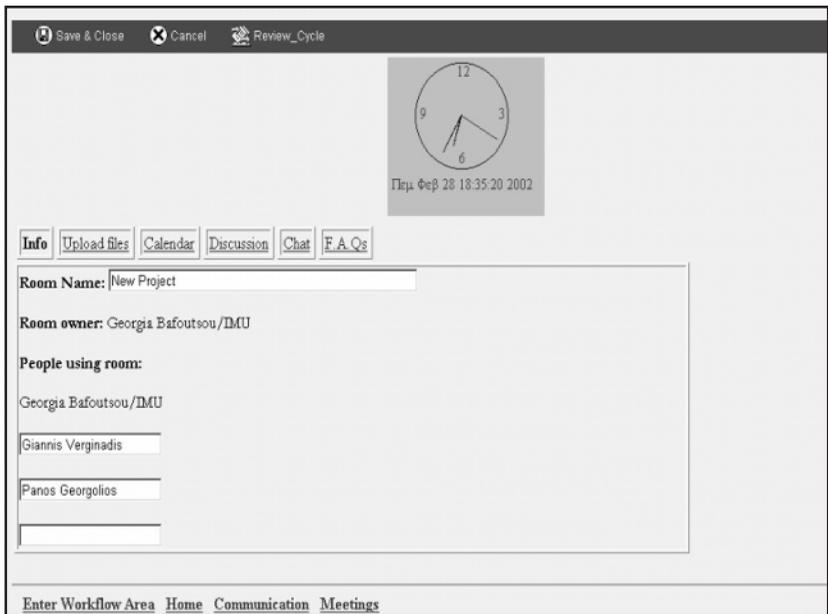


Figure 7. Real-Time Text Chat

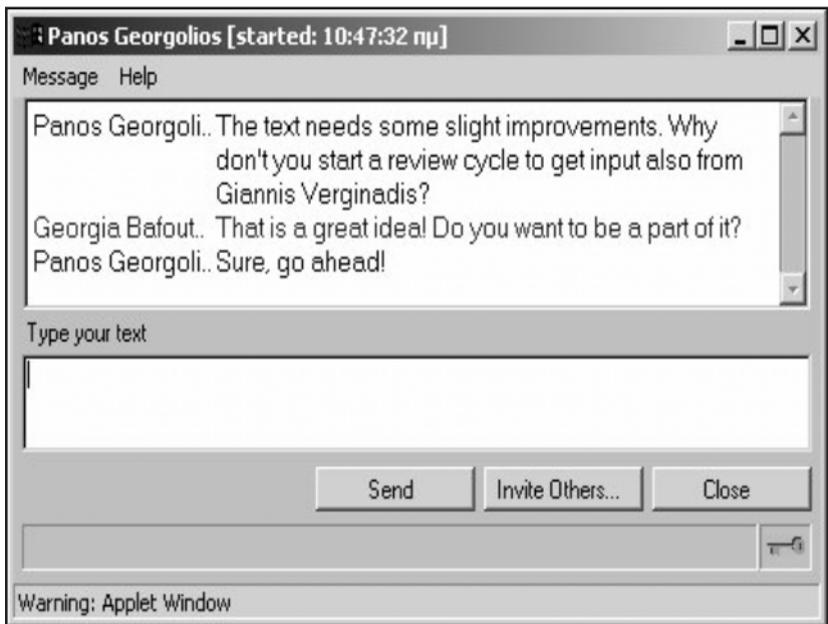


Figure 8. Review Cycle

Server Administrator/IMU

Today 01:43 pm

Room: New Project

Subject: Review of partnership invitation

Attach a file: Browse...

Originator	Review Participants	Review Options
Server Administrator/IMU	Panos Georgolios/IMU Giannis	Type of review: One reviewer at a time Time Limit Options: Move to next participant after time limit expires Time Limit (days): 2 Notify originator after: each reviewer

Submit
 Save but do not submit

Comments:

b i u 10 Sans Serif

invitation. These documents are available for viewing and editing by all authorized room users. *Figure 6* demonstrates the room and its users.

The next step is the notification of the users' associates for the existence of the room, so as to connect to C-CUBED and proceed with the preparation of the partnership invitation. Therefore the user takes advantage of the facilities of the communication subsystem.

A first draft of the invitation of partnership is already complete, but the contribution of the rest of the team is required. At first, a chat is conducted between the user in question and another room user (see *Figure 7*).

In sequence, the document of partnership invitation is entered in a review cycle, as depicted in *Figure 8*.

The derived document will then obtain management approval, in the context of the "Form a VC" workflow process, and will be sent to the potential partner.

The "Form a VC" workflow process includes the approval of the partnership invitation by the management and the response of the potential partner. In case of a positive result, the preparation of the collaboration agreement and its review by the legal department and then the management follows. Concluding, the partner is requested to sign the contract and the partnership is officially valid (*Figure 4*).

We should note that the partner is not a single person but a whole company, which is asked to be a part of the virtual consortium. The user who takes part in the workflow process is an authorized member of this company. C-CUBED is not involved with the processes taking place in the company-partner as far as the decision for the partnership is concerned.

During process modelling we have made a provision for loops, which cover potential input of the legal department as well as of the management team for each company participating in the virtual consortium. Also, it is possible that several negotiations occur in the effort of reaching agreement with potential partners.

In this use scenario, we examine the case of the legal department proposing the revision of some contractual terms. As a result, the flow of work is directed back to the bidding workgroup in order to implement the required changes. Let's assume that the user, who claims the work item, faces difficulties in completing the task. Therefore s/he makes the decision to start a discussion in a dedicated space (foyer) and get the input of experienced colleagues (see *Figure 9*).

The flow of work will move on to the legal department as long as all open issues are resolved.

Figure 9. The Foyer

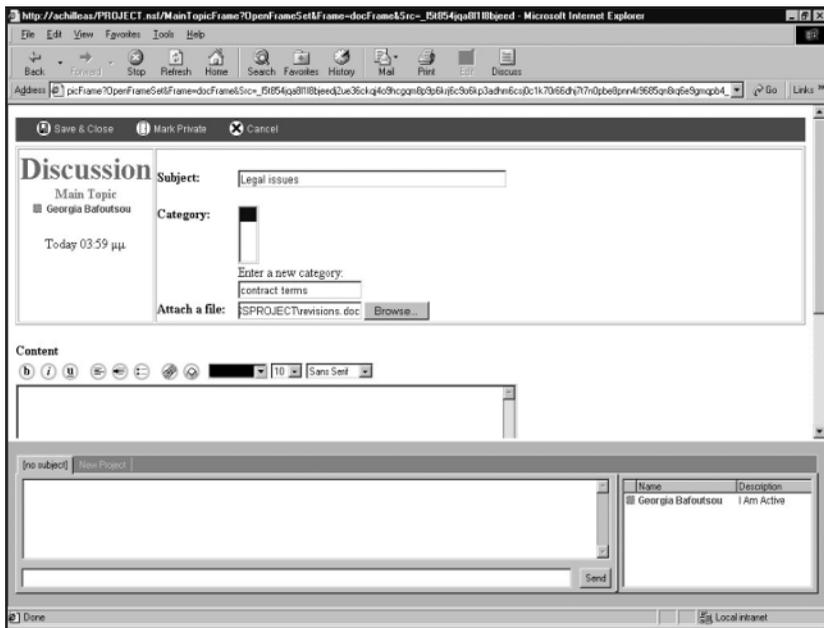
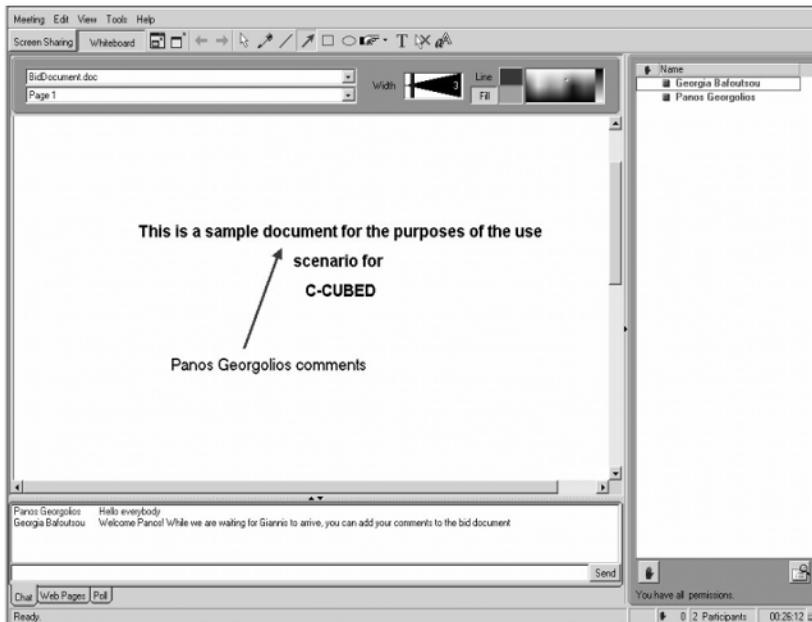


Figure 10. Presentation of the Bid Document Using a Whiteboard



Finally, a real-time meeting is organized among the members of the consortium. The purpose of this meeting is to finalize the bid document. In this context, the document is presented in a whiteboard, where the participants add their comments (see *Figure 10*).

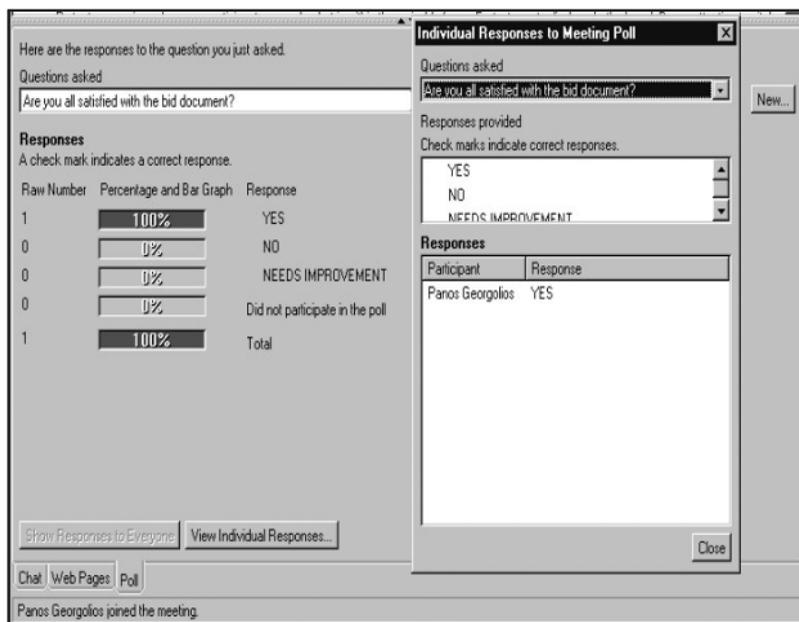
The meeting ends with the conduction of a poll, which reveals the standpoint of the VC members concerning the specific bid (see *Figure 11*).

Discussion and Concluding Remarks

Collaborative work based on information sharing is becoming a necessity at the personal as well as professional level. Collaboration requirements include three discrete elements: communication in case of remote interactions, automation of business processes, and cooperation through shared information objects.

Interacting through common information objects (cooperation) is the key dimension of collaboration applications. In this chapter we examined 60 commercial products and research prototypes, the majority of which provide the possibility

Figure 11. Conduction of a Poll



of common access to files and documents, while some of them also offer tools for their editing, either synchronously or not. Most of these systems also support informal communication among users.

Electronic calendar tools partially support coordination, while one can identify systems that also include basic workflow management functionality, mostly by putting documents in review and approval cycles. These systems are usually applied in cases of planning and designing informal processes, as, for instance, they allow the creation of a document, where all common actions of a project team are scheduled, or facilitate the conduction of a meeting for decision making. However, the users' activities are neither controlled nor monitored, but it is left up to them to decide how they will work (individually or in the context of a team) and what they will work on.

Consequently, collaboration systems that specialize either in communication or in cooperation or even combine both dimensions provide limited support for coordination during teamwork. One can locate shortcomings in the functions of business process definition, where neither workflow automation nor workflow monitoring is possible.

In the following paragraphs we present the main functional and technical characteristics of the C-CUBED system — which was presented in the previous

sections of this chapter — that raise these shortcomings and pinpoint areas for future research.

C-CUBED Characteristics

Earlier in this chapter we described the functions of the collaboration systems and classified them in three dimensions. C-CUBED includes a sufficient subtotal of those functions so as to adequately deal with all three collaboration dimensions.

The functions of the C-CUBED prototype are as follows:

- electronic mail
- asynchronous discussion
- real-time chat, using written messages
- screen sharing
- whiteboard
- file and document sharing
- task list
- meeting scheduling tools
- workflow management

Table 9 presents C-CUBED in relation to the collaboration dimensions. This table is similar to *Table 6*, including the definition and basic functions of each collaboration dimension, with the difference that the outer right column indicates the grade of support of each function by the proposed C-CUBED system.

Figure 12 provides graphically the incorporation of C-CUBED in the space of collaboration dimensions.

Each corner of the triangle corresponds to a specific e-collaboration dimension. Inside the triangle the various collaboration functions have been positioned according to the degree of support they can provide to each e-collaboration dimension.

Both *Figure 12* and *Table 9* make it obvious that the proposed C-CUBED prototype encompasses the majority of functions of all three dimensions. Workflow management is amalgamated with informal, direct communication, realized through electronic mail messages, asynchronous discussion, and real-

Table 9. C-CUBED in the Space of Collaborative Dimensions

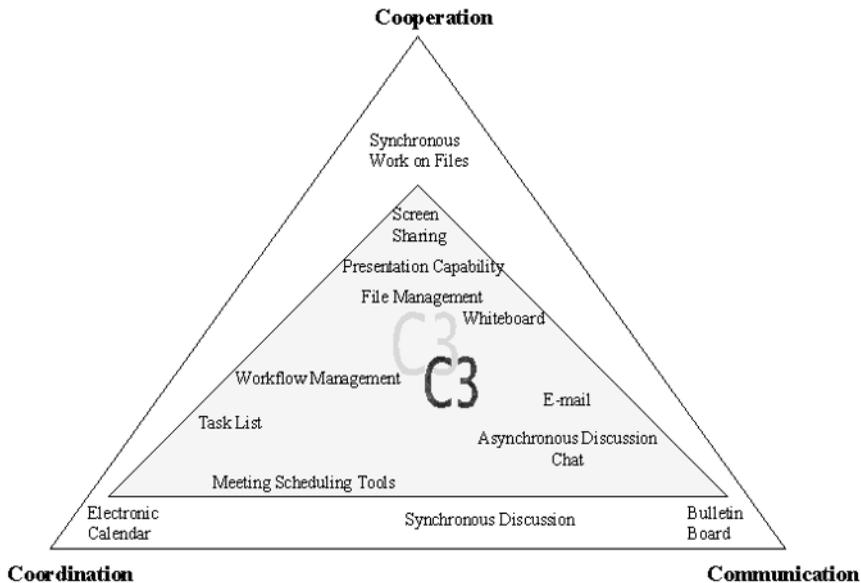
Collaboration Dimensions	Definition	Functions	C-CUBED
<i>Communication</i>	Explicit interaction of two or more people aiming at the exchange of information of any kind	E-mail	●
		Chat	●
		Bulletin Board	○
		Synchronous Discussion	○
		Discussion	●
<i>Cooperation</i>	Implicit interaction taking place through reference to a common artifact	File Management	◐
		Synchronous Work on Files	○
		Whiteboard	●
		Screen Sharing	●
		Presentation Capability	●
<i>Coordination</i>	Programming and settlement of activities performed by the parties involved in a collaboration process	Task List	◐
		Meeting Scheduling Tools	◐
		Electronic Calendar	○
		Workflow Management	●
●	Full Support of the function		
◐	Partial Support of the function		
○	No support of the function		

time chat as well as with indirect interaction accomplished through editing of files, accessing a whiteboard, screen sharing, and conducting and watching PowerPoint presentations.

At the same time with executing a task in the context of an automated workflow, communication with the other participants in the process is possible. The purpose of this communication can, for example, be answering questions that arise during the fulfillment of a certain task or the clarification of operational topics. Also, studying relevant documents stored in the system during previous instances of the process can prove to be particularly useful, since it exploits previously obtained knowledge and experience.

The main technical and functional choice for the C-CUBED system is the concept of “virtual rooms,” in order to allow the easy transition between individual and group work as well as between synchronous and asynchronous interaction. Defining a room as a place of individual or group work depends

Figure 12. C-CUBED in the Space of Collaborative Dimensions



exclusively on “the going in and out” of its users. There is no technical distinction between rooms used by an individual and those that host groups, since the tools required for the successful individual management of a space are identical with those that constitute a room functional for the needs of the team.

Therefore, when a user enters an already occupied room, this space becomes a fully functional collaboration environment. Moreover, when team members show up in their reserved room, they automatically begin to work in real time. In case they wish to interact asynchronously, this can be achieved by “leaving” artefacts in the room.

Future Perspectives

Research on the integration of the three e-collaboration dimensions is still open. Various topics can be located that require special attention, extensive study, and research.

One of these topics refers to the issue of flexible workflows, which differ from structured, rigid ones in the sense that they allow their alteration during enactment (Kammer & McDonald, 1999). Especially interesting in this case is the support for defining collaborative business processes (Haake & Wang, 1999).

Knowledge management and its combination with workflow management (Papavassiliou, Mentzas, & Abecker, 2001), communication, and cooperation is a second open and interesting research field (Hasenkamp & Hilpert, 2001). Managing the corporate knowledge assets is critical for the successful operation of an organization, and the potential combination of e-collaboration functionalities with workflow management can prove to be a valuable step towards this direction.

Moreover, the virtual reality field generates fruitful research areas in e-collaboration, which include, for example, the interaction of humans with dynamic environments produced with the use of computers (Li, Chang, Hsu, Kuo, & Way, 2001; Wann & Mon-Williams, 1996).

Finally, investigating the social nature of collaboration and the impact of the human factor on the successful outcome of the processes involving remote interaction is always timely (Hayes, 2001; Pendergast & Hayne, 1999; Ramarapu & Simkin, 1999).

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Chapter III

Collaborative Product Development

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Abstract

This chapter discusses the roles of electronic business solutions (EBSs) in supporting collaborative product development (CPD). Two fundamental questions are of primary interest. One is when and where EBSs should be applied for what CPD decision activities. The other is how EBSs should be designed and developed to maximize their usefulness and usability in supporting CPD decision activities. The author advocates an approach based on decision activities. By this approach, CPD is considered as an extended enterprise business process, which is in turn decomposed into relatively simpler business decision processes (e.g., design specification, design review and release, design change management, etc.). Such decomposition takes place towards the level where appropriate EBSs can be most cost-effectively designed, developed, and applied. The logics and data requirements of these business decision processes form the natural basis for designing the navigations and user interfaces as well as the back-end databases and middleware for the corresponding EBSs. Individual EBSs related to product design and development decisions are then collated and deployed to form what is described in this chapter as a collaborative product commerce (CPC) portal — a special enterprise portal. The proposed approach is demonstrated with several examples as has been followed by many researchers and practitioners.

Introduction

Product development and design have been recognized as the heartland of both manufacturing and service industries and received considerable attention and investment from both academic researchers and industrial practitioners. Their importance, complexity, and challenge have been widely recognized and emphasized in the vast literature accumulated over the years. Excellent textbooks have appeared with varying emphases. Theories and methodologies, emerged from good practices accumulated over the years by leading practitioners and researchers, have been collected in these texts. In terms of research, several excellent literature reviews have been conducted (Balachandra & Friar, 1997; Brown & Eisenhardt, 1995; Cusumano & Nobeoka, 1992; Finger & Dixon, 1989a, 1989b; Griffin & Hauser, 1996; Krishnan & Ulrich, 2001; Shocker & Srinivasan, 1979; Whitney et al., 1995).

Product development and design are distributed and collaborative in nature. Multiple disciplines and heterogeneous tools are used. Teamwork is essential through seamless tool integration and better coordination of human activities. Researchers and practitioners have always been instrumental in applying the latest information and communication technology (ICT) to deal with different aspects of collaborative product development. There have been enormous efforts in devising computer-supported environments to facilitate and enable collaborative product development. Early developments and achievements in computer-supported concurrent engineering (CSCE) had been reported in an ASME workshop organized by Sriram, Logcher, and Fukuda (1989) and a special issue in the *IEEE Computer* journal (*Computer Support*, 1993). Further developments are widely posted at several Web sites, e.g., <http://www.cenet.org/> and <http://www.ceteam.com/>.

With the increasing popularity of the Internet and World Wide Web (Web or WWW), there have been renewed attempts recently. One of the first and most significant initiatives in the development and application of Web-based systems in CPD is the American research project — the MADE (Manufacturing Automation and Design Engineering) program. MADE is a DARPA (Defense Advanced Research Projects Agency) program initiated in 1992 and completed in 1996. The MADE program supports research, development, and demonstration of enabling technologies, tools, and infrastructure for the next generation of design environments for complex electromechanical systems. This program involved a number of major research centers/groups, resulting in valuable publications at conferences, in journals, and on the Internet (Bryant et al., 1996; Cutkosky, Tenenbaum, & Glicksman, 1996; Petrie, 1996; Whitney et al., 1995; Will, 1996). This program is concerned with comprehensive information modeling and the design tools needed to support rapid design of electromechanical

systems. This program emphasizes the notion of “tag team” design, in which each designer performs the functions he or she is best at while leaving behind in a design information web enough information for other designers to pick up wherever the others left off. MADEFAST was a demonstration of this approach conducted by several research groups that collaborated in the design and manufacture of a prototype sensor-array aiming system. The MADE program continues as the RaDEO (Rapid Design Exploration and Optimization, 1997) program. Since then, significant progress has been achieved in Web-based product design and manufacturing (Erkes et al., 1996; Huang & Mak, 2003). Leading software vendors have capitalized upon the recent progress and developments in design theories and methodologies, with some excellent electronic business solutions developed and available to support CPD activities. WindChill from PTC provides a suite of example EBSs for supporting CPD.

This chapter focuses on discussing the roles of EBSs in supporting CPD. The chapter is primarily intended for two audience groups. The first group includes such audience members as managers/engineers involved in product development projects who can appreciate the potential of EBSs. This audience group would be more interested in questions like: What EBSs should be chosen? Where and when should EBSs be applied for which decision activity/activities to maximize the benefits? What do I need to prepare and/or change in order to use EBSs?

The second audience group includes those managers/engineers who can recognize opportunities for initiating new projects to design and develop new EBSs to support CPD. This audience group would be more interested in questions like: What EBSs should be developed? Which decision activity/activities are generic and important enough to warrant an EBS? How can I minimize the user’s efforts and thus maximize the benefits?

The chapter is arranged as follows. The following section treats CPD as a project consisting of work packages and a business process including decision processes, respectively. Then, the chapter explains that both treatments converge into a Web portal for CPD. Next, the chapter summarizes a few example EBSs used in CPD. A case study on collaborative design review is then given. The chapter is finalized by highlighting some of the potential benefits of EBSs for CPD.

CPD in Virtually Extended Enterprises

Let us raise two questions here: *What EBSs should be designed and developed for CPD?* and *Where can they be applied most effectively and efficiently in*

order to support CPD? There have been considerable efforts attempting to design and develop ambitious total CPD solution where products can be designed and developed. Despite impressive progress in some directions, there are fundamental limitations for such attempts. It has not yet been demonstrated that the complexity of CPD is itself reduced by the use of Web-based solutions. The author of this chapter maintains that the CPD complexity should be reduced by the human engineers, possibly with the help of ICT, and EBSs are applied to solve subproblems of less complexity. In this respect, we need appropriate schemes for complexity reduction.

This chapter discusses two standard methods for complexity reduction. One is to consider CPD as a backbone business process within an organization and then break it down into lower-level business processes and decision activities. The other is to consider CPD as a project for developing a specific product. When coming to the decision level, these two methods serve essentially the same purpose: identify and apply the right EBS to support making the decisions most effectively and efficiently.

Product Realization and Design Process as Business Processes

From a macro perspective, the product realization process (PRP) is a business process widely considered as the critical backbone of a manufacturing (and service) organization. It starts with the recognition of market needs and conception of product ideas; proceeds through numerous key stages such as product innovation and design, manufacturing and purchasing of components and raw materials, assembly and testing of the final products, warehousing and delivery of products, and technical supports and customer service; and finishes with the disposal and retirement of the products that may well trigger the reverse logistic process. The PRP has a major effect on how a company organizes its operations.

The product development/design process (PDP) is just one stage in PRP. From a micro perspective by zooming in this stage, the PDP becomes itself a business process. In a narrow sense, the PDP is mainly concerned with producing a product design from a set of design specifications ready for full-scale production. The contemporary understanding of the PDP takes much broader view. In fact, no difference has been drawn between the scopes of the PRP and the PDP because the concurrent engineering approach favors the simultaneous consideration of the total life-cycle issues in product design. The main difference between the PRP and the PDP lies in that physical forms of products are involved in the PRP, while the PDP only involves the planning and decisions related to the flow

meet the special requirements appropriate for the product under development. The purpose is the same: to reduce the complexity so that effective decisions can be made efficiently. Once the decision activities have been identified through the complexity reduction process, the two questions (*What EBSs should be designed and developed for CPD?* and *Where can they be applied most effectively and efficiently in order to support CPD?*) raised at the very beginning of this section can be discussed in more clarity.

Generally speaking, those decision activities that are logically related to each other but only loosely coupled with other groups of decision activities should be grouped together and incorporated into one EBS.

Similarly, the designer would expect to search for an EBS appropriate for supporting a group of decision activities that are logically interrelated but relatively independent of other groups.

Web-Based Decision Supports Within and Outside Enterprises

We have used the term EBS (electronic business solution) already without in-depth description. Let us first introduce the concept of Web applications. A Web application is defined as any software application that depends on the World Wide Web, or simply Web, for its correct execution (Gellersen & Gaedke, 1999). Hence, software systems that are explicitly designed for delivery over the Web,

Figure 1. Typical CPD Decision Activities

New Product Development Process			
Specification	Concept Design	Detailed Design	Production Design
<ul style="list-style-type: none"> • Establish specifications collaboratively • Avoid ambiguity and information distortion • Set technical targets • Articulate trade-offs • Identify early changes 	<ul style="list-style-type: none"> • Key product and process technologies • Product architecture • Contribute key ideas/concepts/critical components • Participate in concept evaluation • Establish interfaces between product subsystems 	<ul style="list-style-type: none"> • Selection of proprietary parts and components • “Black box” designed parts and components • Tolerance design • Detail controlled parts and components • Prototype testing and demonstration • Design for manufacturability • Material selection 	<ul style="list-style-type: none"> • Make or buy decisions • Tooling and fixturing design • Equipment acquisition • Design for manufacturability • Quality control and assurance • Raw materials
Supplier Involvement			

of and operations on materials. In other words, the PDP deals mainly with planning, while the PRP deals with execution and control. Planning, execution, and control are normally addressed within the same decision support framework. In this connection, it is difficult and unnecessary to divide EBSs between the PRP and the PDP.

All stages included in the PDP can be further extended into sublevel business processes that are weaved together with each other and other business processes in the organization. For example, the stage of product design specification (PDS) can be zoomed in to form a sublevel business process — customer and market requirement analysis, closely related to the marketing and sales process in the company. In addition, there are other processes such as engineering change management and design review.

Work Breakdown Structure in CPD Projects

Developing a product collaboratively is a project normally divided into so-called work packages. The concept of work breakdown structure (WBS) plays an important role in project management. The project WBS displays and defines hierarchically the product to be developed or produced by hardware, software, support, and/or service element and relates the work scope elements to each other and to the end product(s). Because it provides the framework for building a project, it should be created early in the planning phase. The WBS is the foundation for project planning and control. It is the connecting point for work and cost estimates, schedule information, actual work effort/cost expenditures, and accountability. It must exist before the project manager can plan these related and vital aspects of the project, and they all must be planned before the project manager is able to measure progress and variance from the plan.

The WBS is a convenient method for dividing a project into smaller tasks or activities. It subdivides the project into tasks that are each defined, estimated, and tracked on tangible, deliverable items. It is at such levels where EBSs are introduced to make specific contributions.

CPD Decision Activities

Whether we take a business process analysis approach or a project work breakdown structure approach to decompose CPD, we will eventually reach such levels where specific product design decisions have to be made. The former will normally produce a generic roadmap of typical CPD design decisions and decision activities. In contrast, the latter will customize such generic models to

for example, Web sites, and that use the Web infrastructure for their execution are Web applications. For example, many information systems that were designed and built prior to the Web are now wrapped and made available as Web applications through the use of Web browsers.

Electronic business solutions (EBSs) are decision support systems based on the Web and/or Internet. They are essentially Web/Internet applications used to facilitate business decision making and executing activities. Here, the use of the word *solutions* instead of software systems deserves some explanation. The software is only part of a solution. A solution includes other elements such as good practice guidelines.

Decision activities often involve multiple decision makers (EBS users) playing different roles in the decision process, such as supplying input data and interpreting output results. These decision makers may come from different functional units other than design engineering within the enterprise or from external business partners outside the enterprise. Even in the case that all members come from different departments of the same enterprise, they may well be geographically dispersed, in addition to their diverse disciplines.

Enterprise Portal for Collaborative Product Commerce

Individual EBSs can be deployed and applied separately as if they are stand-alone systems. In this case, their access and operation are independent of each other as if they are used as different systems. Alternatively, EBSs are deployed and configured such that they are used as if they belong to the same system, with a single entry point and amalgamated according to the user's roles in the enterprise. Such EBSs form what is called an enterprise portal. EBSs of the enterprise portal can be sorted according to the corresponding business processes and decision activities, thus forming special-purpose sub-portals. For example, EBSs related to product realization and development form a collaborative product commerce (CPC) portal, as shown in *Figure 2*.

Aberdeen Group (2000) defines CPC as “a suite of software and services that integrates several product-centric business processes across multiple independent enterprises into a single, closed-loop solution.” CPC solutions are inherently Web based and extensively use data sharing, collaboration, and visualization technologies. CPC represents a set of Web applications that encompass business processes related to all product-centric activities across the entire product life cycle, from the initial product design, product engineering and

development, manufacturing and logistics execution, field service and technical support, and feedback from these stages to be incorporated into the next round of improvement product design.

CPC Portal Server

Among all the Web applications in a CPC portal exists a special Web application at its center. This special Web application is called the CPC portal server, which is simply a set of software solutions on the Internet hosting Web contents, services, and applications. It is the integrator and controller of everything and everybody involved. It provides a platform for portal operators to enable interaction between end users and application/service providers. The platform enables the procurement and provision of Internet-based services.

The CPC portal server is implemented as a set of software components that can be executed on one or more server computers. A very small implementation can fit on one computer, but in most cases, a server farm will be deployed to balance the load between multiple computers. The server is designed for maximum scalability and reliability, so that if a server box in a farm fails, its load is automatically assigned to another box.

At present, there are very few commercial CPC portal servers on the market despite all the great potentials.

CPC Portal Users

Users of a CPC portal comprise different strata of parties or individuals who are participating in the product development and realization process. In most cases, users can be categorized as either internal or external. To its CPC portal, however, the difference is no longer between internal and external but lies in the differing degrees of access authority. Such authorities are determined by the roles that they play during the product development and realization process.

No matter what privileges individual users are assigned, they are divided into two groups:

- Information creators who not only need quick and easy access to the data but also the means to make substantial modifications to those data. Process planners, designers, analysts, and manufacturing engineers are some of the example users in this group.

Figure 2. Collaborative Product Commerce (CPC) Portal



- Information consumers who primarily need to view data and read/access related material. Example users include individuals in management, marketing, sales, design reviewers, support, suppliers, and shop-floor personnel.

Information consumers need a low-cost, low-maintenance, and easy-to-use environment to view the information and perhaps add/publish simple attributes. For these users, the Web-based server is the only viable solution.

The “information creators,” on the other hand, will use the server as a means of communication and as a decision support system on high-end graphical user interfaces for concurrent design and collaborative engineering. This group of users demands a fast and versatile search and publishing capability, accessible from CAD and PDM systems. URLs are embedded in the databases that provide additional information for making modifications. Although a Web-based server may not be the only way to make data available to this group of users, the need for collaboration and information sharing at the extended enterprise level makes the Web-based solution very attractive.

EBS Providers and Portal Operator

The CPC portal operator is responsible for managing and maintaining the CPC portal. The interesting question here is: Who should take the role as the portal operator? There are several options. For example, the manufacturing company itself can act as the portal operator. This requires the company to invest in the hardware and software, as well as the human resources. Alternatively, a few manufacturing companies form a group (consortium) to share the same portal, with the investment amount also shared out among the group members. Furthermore, the portals can be operated by specialist portal operators who have the hardware technologies, and skilled personnel can be invited to manage the portals.

Application developers first develop the technology solutions or applications. The applications are then licensed or sold to the application providers although applications developers may also serve as the application providers in some cases. The CPC portal server is a special Web application, and therefore the portal operator is a special application provider. The CPC portal operator subscribes to the services and applications on behalf of the users.

The CPC portal incorporates and hosts the applications as part of its components in addition to those built-in Web applications. Alternatively, the applications providers host the applications separately, while links are incorporated in the

CPC portal to provide access points so that both the service providers and subscribers are able to access the services as the portal users.

Third-party applications providers are able to interact with a service aggregator, e.g., the CPC portal operator, after signing a contract with the operator and receiving a provider account and password.

Special Features of CPC Portal

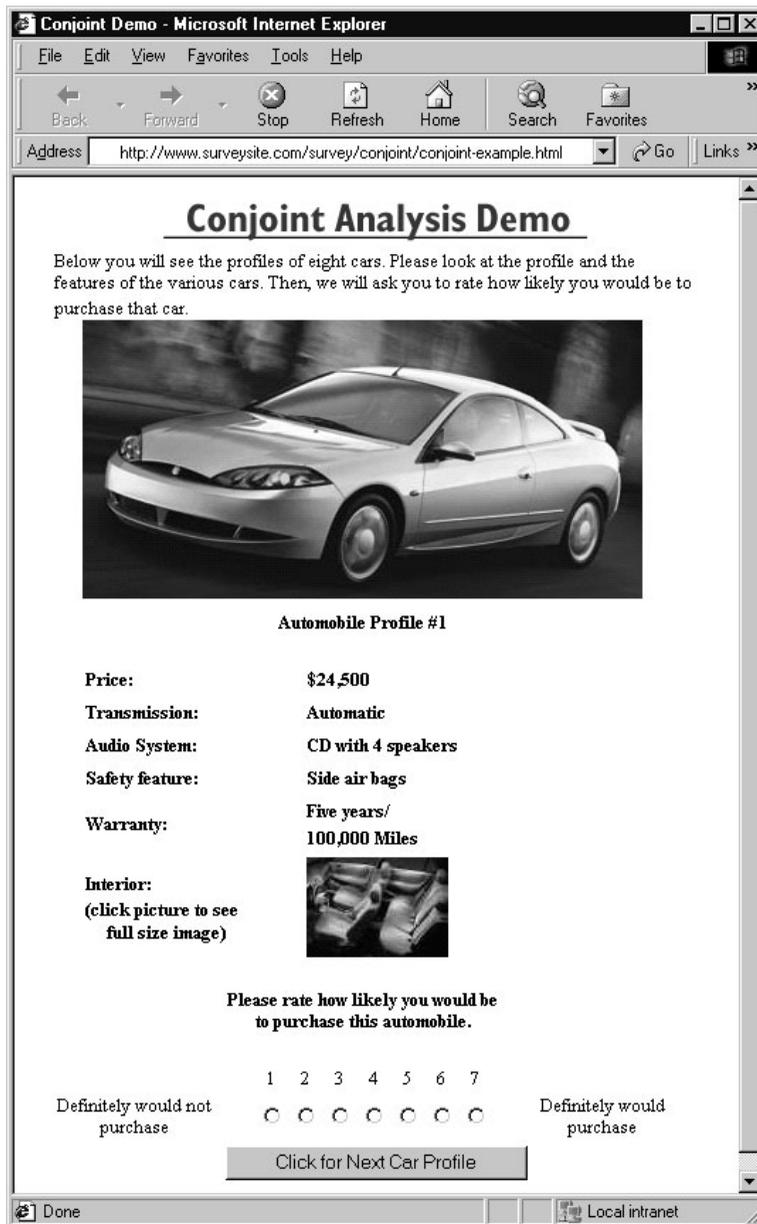
CPC is complex, and the technology requirements are far more extensive than those associated with the e-commerce. This can be understood from the following aspects:

- Some Web applications in product development and realization are focusing on the design of new products (based on customer requirements), which are not available on the market yet.
- The transactions between players involve not only data and information but also the exchange of knowledge.
- The transaction of information, both in terms of variety and intensity, requires more complicated techniques. For example, 3-D display and manipulation of geometrical information of products and processes on the Internet through the Web remains a great challenge.
- The negotiation and collaboration between team participants within an enterprise (design, manufacturing, assembly, marketing, management, etc.) and/or across different enterprises (business partners, suppliers, customers, etc.) have a higher frequency and greater intensity when compared with ordinary e-commerce applications.

Electronic Business Solutions for CPC

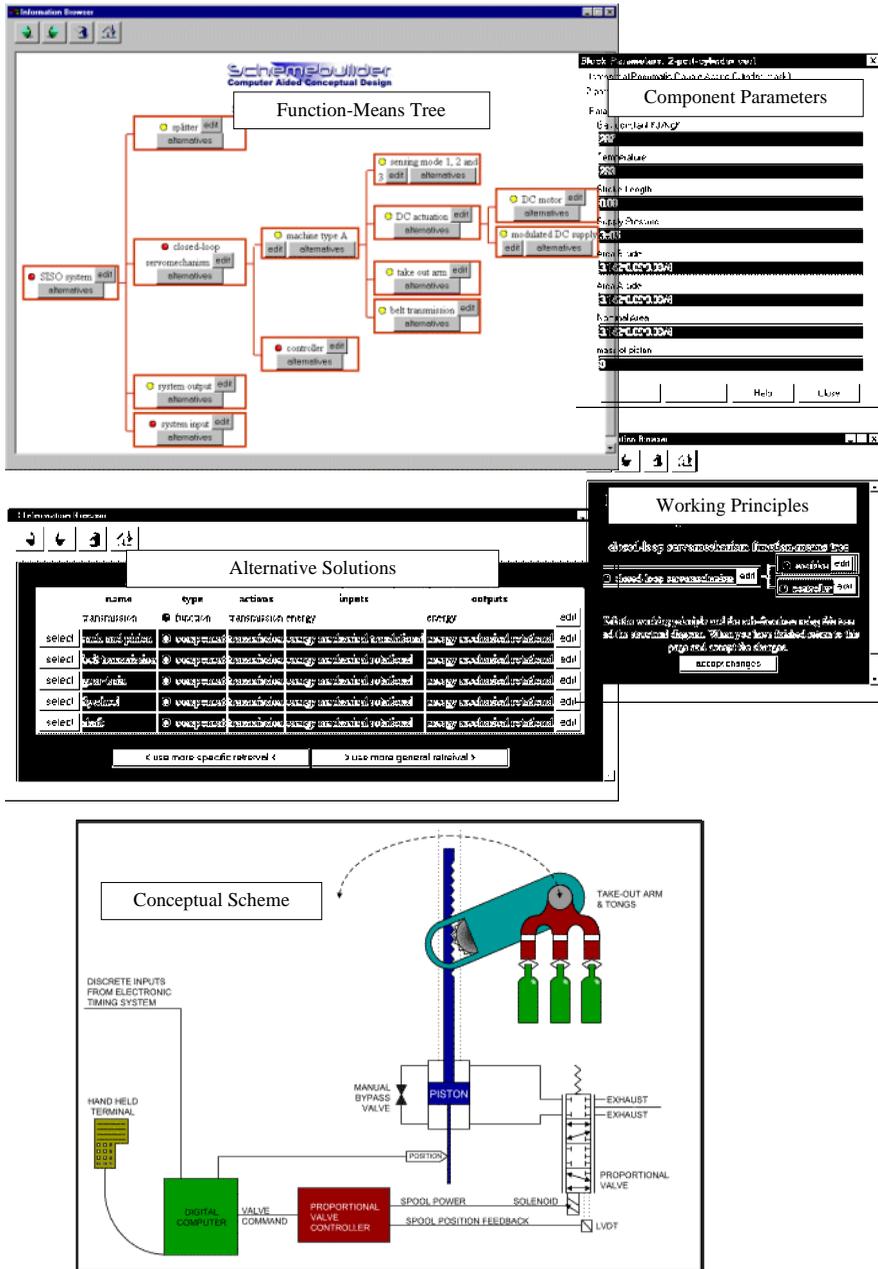
The chapter has mentioned that the classic techniques in business process management and project management can be used to decompose CPD into sublevel business processes consisting of interrelated decision activities. Accordingly, there have emerged two general groups of EBSs for supporting CPD. The first group includes those that are dedicated to supporting major decision activities of key business processes/operations involved in product development and design. The second group of EBSs includes those that are especially

Figure 3. Web Application for Market Testing of Product Concepts



Source: <http://www.surveysite.com/survey/conjoint/conjoint-example.html>

Figure 4. Schemebuilder for Conceptual Product Development



Source: <http://www.comp.lancs.ac.uk/edc/schemebuilder/>

designed and developed to facilitate and support the group or team for complexity (“divide and conquer”) management. This section presents some examples of these two types.

Market Research and Concept Testing

Web applications make it possible to carry out online market research and product concept testing. *Figure 3* shows an example of carrying out a conjoint analysis at a Web site (<http://www.surveysite.com/survey/conjoint/conjoint-example.html>). Dahan and Srinivasan (2000) developed an Internet-based product-concept testing method which incorporates virtual prototypes of new product concepts, substituting them for physical prototypes. The method can be used with either static representations of the products or dynamic representations that demonstrate how the product works through a simulated video clip. The objective of this method is to allow design teams to select the best of the new concepts within a product category with which to proceed; then there is no need to develop physical prototypes.

The general procedure is as follows:

- The manufacturer sets up a Web site for customers to voice their requirements.
- The manufacturer (product development team) reviews the customer requirements in order to establish design specifications for the new product.
- The design specifications (customer requirements) are then used to formulate design concepts (this is conceptual design, which is discussed in the next section).
- Virtual (and/or physical) prototypes are prepared for candidate concepts and displayed on the Internet.
- Customers are invited to test these concepts at the Web site.
- The team on the manufacturer’s side reviews the customer responses and proposes changes to the conceptual design.
- The project proceeds to the next stage.

As virtual prototypes cost considerably less to build and test than their physical counterparts, design teams using Internet-based product-concept research may be able to afford to explore a much larger number of concepts. Virtual prototypes and the testing methods associated with them may help to reduce the uncertainty

and cost of new product introductions by allowing more ideas to be concept-tested in parallel with target consumers.

Collaborative Early Product Definition

Early product definition, also known as conceptual product design and product conceptualization, is a collaborative effort of the team members. Web applications are particularly attractive. While Chapter 12 is dedicated to this topic, the Schemebuilder is an example of a computer-aided tool for product conceptualization, as shown in *Figure 4*. Although it is not yet a Web-based tool, it facilitates the development, refinement, and selection of design concepts through a collaborative effort.

Schemebuilder is a software tool that enables the rapid development of conceptual product designs, known as schemes. The computer helps the user to explore alternative concepts and produce design simulations. The tool provides a design synthesis environment which is coupled with a structured knowledge base. The knowledge base provides intelligent access to design knowledge and a component database. This is integrated with a simulation environment for design analysis, capable of cross-domain, object-oriented simulation.

Both abstract and concrete knowledge are represented. The knowledge and experience of any user may be added. Case-based retrieval is used with multidimensional, hierarchical indexing. Three types of knowledge are represented: means of achieving functions, working principles or given function structures that experience has shown to be successful, and components that embody the means. Very complicated knowledge may be represented as rules. Advice, triggered when relevant circumstances arise, may be accepted or ignored. Control advice has been embedded, which uses the automatic simulation capability. Schemebuilder is capable of automatic simulation generation made possible by the use of object-oriented models. The simulation is run in Matlab, for which a mechatronic model library has been built.

Collaborative Design Review and Engineering Change Management

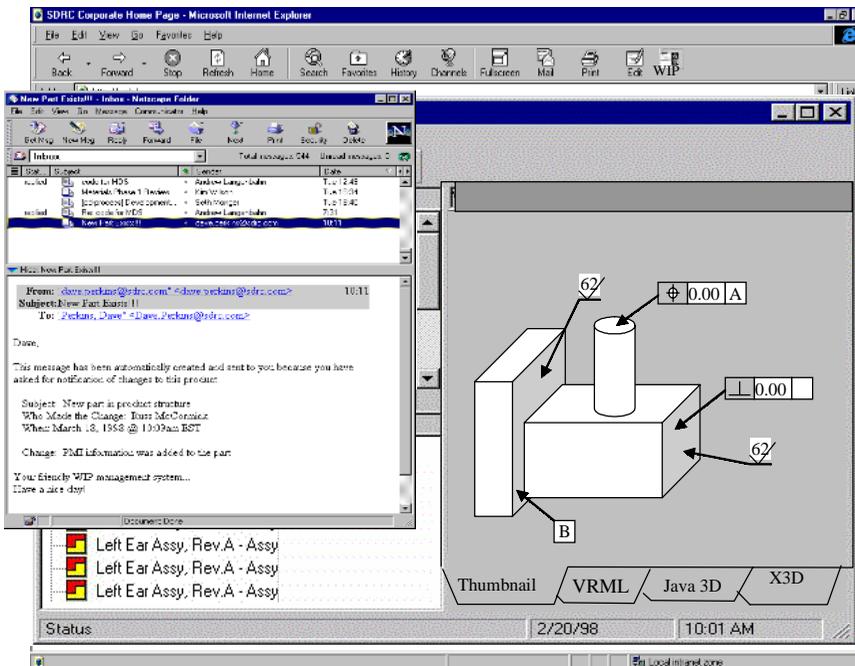
Product design review (PDR) involves gathering and evaluating product design and its concrete plans for realization and improvements, so as to confirm that the process is ready to proceed to the next phase. Product design review is a typical scenario of collaborative product development. A team is tasked with the design and development of a new product. The team consists of members from multiple

disciplines. Some are lead users (key customers), some are core (key) suppliers, and others may come from various functions and units of the organization. Also, all of them are geographically dispersed.

Traditionally, design review is conducted by circulating the documents of a product design, so that they can be reviewed by one member to another. After that, a meeting is then arranged to resolve different opinions. This process is very inefficient, especially when some external members from other regions, such as key customers and suppliers, are involved. Engineering change management (ECM) is another business process in product development, closely related to PDR process. Chapters 10 and 13 discuss ECM and PDR, respectively, in more detail.

Figure 5 illustrates the client user interface for the prototype supporting the engineering change process during the detailed design stage of product development. Note that everything is done electronically with no need to hold group meetings or refer to paper drawings. Also, the review and approval process can take place in a collaborative environment through the Web site and conferencing

Figure 5. Web Applications for Collaborative Design Review



Source: Rezayat (2000)

tools such as NetMeeting and Conference, which will be discussed in the next scenario.

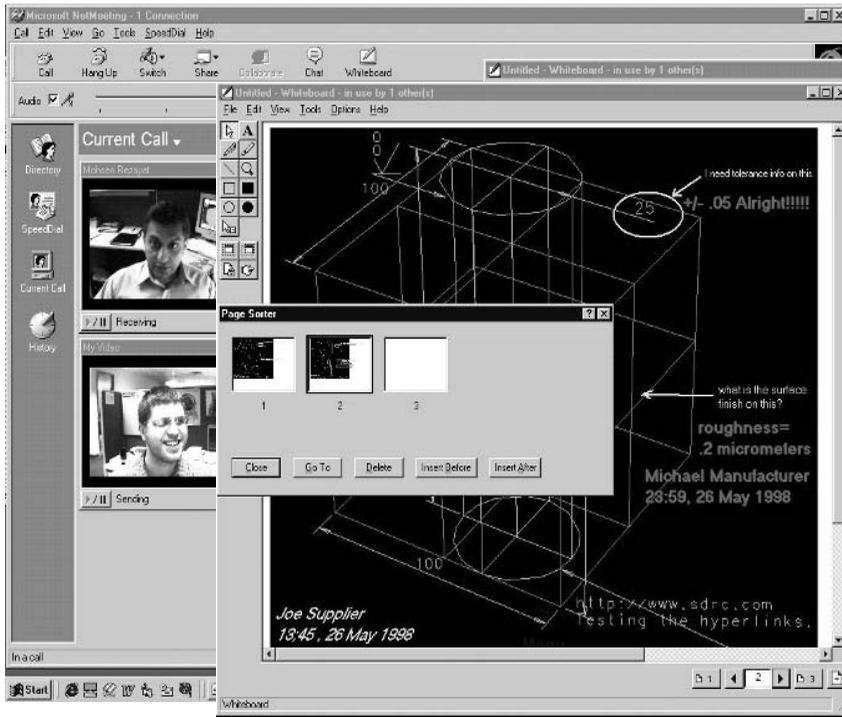
Supplier Chain Integration

Suppliers frequently possess vital product and process technology that can lead to improvements in the new product development (NPD) process. Therefore, there is a need to collaborate very closely with the suppliers at this stage of product development. It is widely accepted that ESI (early supplier involvement) is beneficial to both the buyers and suppliers. Typical benefits include: reduced development costs, early availability of prototypes, standardization of components, visibility of the cost-performance trade-off, consistency between design and supplier's process capabilities, reduced engineering changes, higher quality and fewer defects, availability of detailed process data, reduced time to market, early identification of technical problems, etc.

Here is a simple description of a scenario in which business partners integrate their activities in the extended enterprise. Initially, the end product manufacturer prepares the design of the new product and provides the relevant design and business documents on the Web site. Bids are then invited from low-tier suppliers. Interested suppliers can access the Web site to obtain necessary documents, so that bids can be prepared and later submitted. If necessary, suppliers can use the NetMeeting to hold a live collaborative discussion session with the end product manufacturer. The whiteboard facility is brought up and everyone starts the markup process as appropriate. Comments from chat sessions and markups from the whiteboard are all saved in the Web site. The information is dynamically converted and displayed in the best possible multimedia Web format. Supplier questions regarding a particular feature may be resolved by direct interactions through the Web site. Conflicts between the designers, shop-floor personnel, and the suppliers are all resolved through the Web site.

Figure 6 shows an image of a live net-conferencing session between an imaginary OEM (original equipment manufacturer) and a supplier, who may be thousands of miles apart physically. It is important to note that the whole process takes place electronically, with no need for expensive paper drawings. Notice the presence of audio and video equipment and the ability to mark up and time-stamp the documents electronically. The discussions from each session, stored in a chronicle order in the same file, can be retrieved very easily, and the complete file can be stored in the system.

Figure 6. Supplier Involvement and Selection in New Product Development



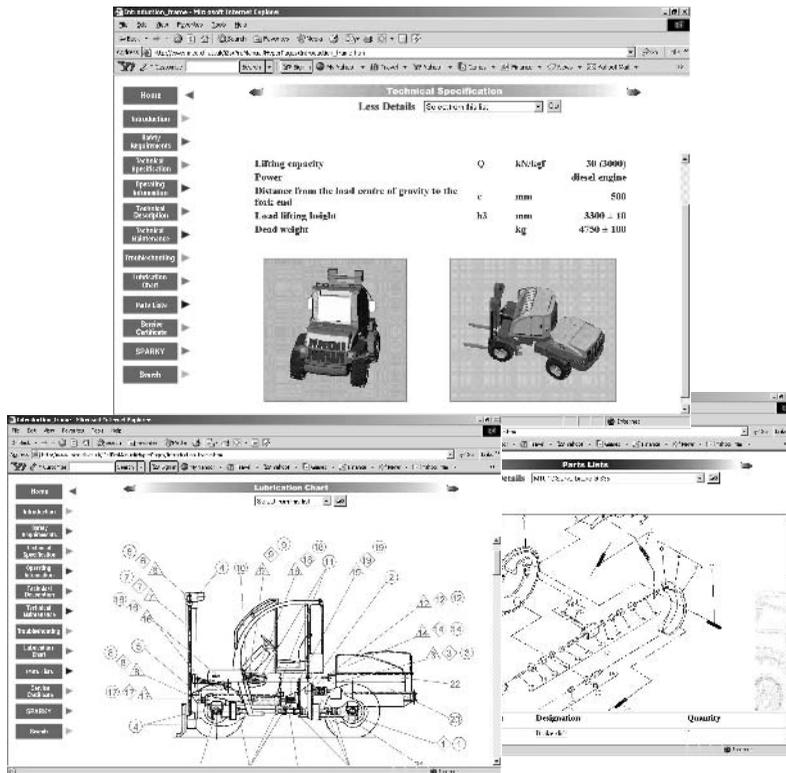
Source: Rezayat (2000)

Intelligent Product Manuals: Technical Supports and Customer Services

Once a product has been designed, manufactured, and delivered, the user rightly expects that it be properly supported. Product support consists of everything necessary to allow the continued use of a product. It may be required for the tasks of planning (for use), handling and installation (preparing for use), operation (use), maintenance and troubleshooting (keeping in use), and upgrading and disposal (changing and ending use). To accomplish these support tasks, the product is brought together with the necessary supplies (consumables and spare parts), equipment (tools and facilities), persons (suitably skilled), and information.

A product support network provides for the production or acquisition, storage, and supply of the above-mentioned support items. It can include product training, technical documentation, help lines, servicing, spare parts ordering, and mainte-

Figure 7. Intelligent, Integrated, and Internet-based Product Manuals



Source: Pham et al. (2000)

nance management. Conventionally, all support items are brought together physically with the product, while information and persons are supplied remotely, e.g., by telephone link. Despite this provision, product support can still be costly, labor intensive, and of poor quality from both the supplier's and user's point of view.

Intelligent product manuals (IPMs) are designed to supply the user with product information of such high quality that the task of the user is effectively de-skilled. *Figure 7* shows an example of an IPM. Thus, the product becomes easy to use and maintain by the virtue of this enhanced task support. The benefits of this type of system are reduced need for skilled persons and for training new technical staff (decreased cost), respectively, and better and quicker task performance (reduced cost and improved performance). Enhanced electronic communication between the hardware, the information systems, and persons involved in product

support creates some other opportunities to be considered alongside with IPMs. These include computer-based training, remote hardware monitoring (e.g., via the Internet), telepresence of skilled persons (e.g., by video links), and integrated spare parts ordering and maintenance management systems.

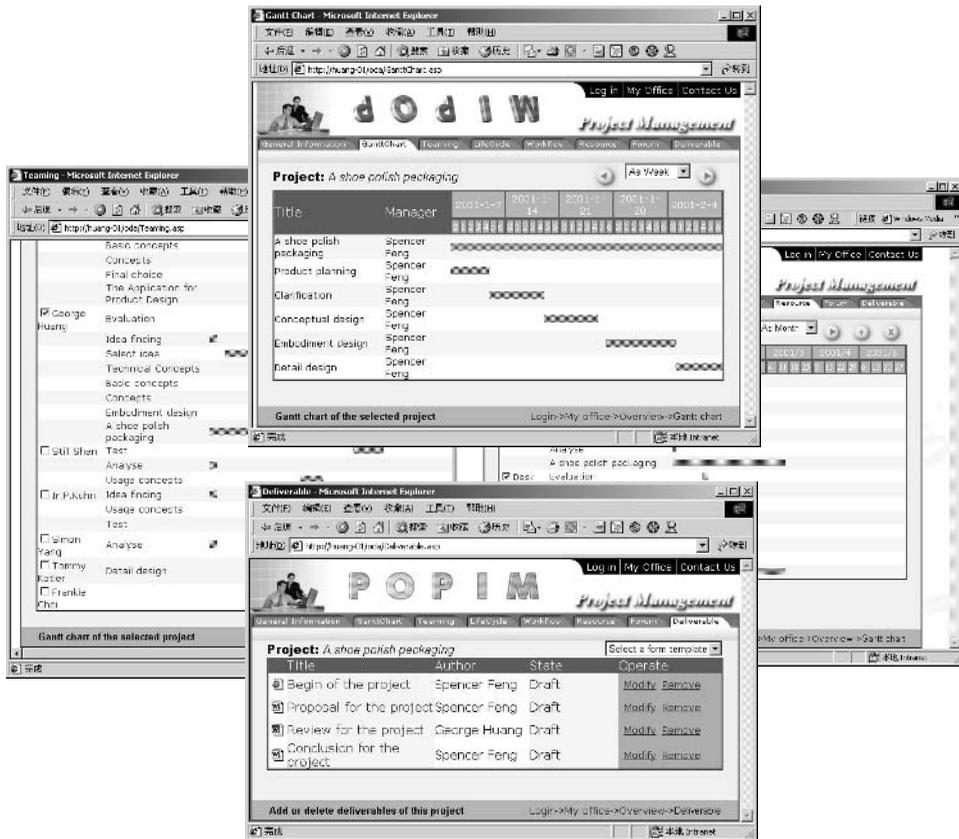
Collaborative Product Development Project Management

Collaborative product development (CPD) has been an area for intensive research for two decades. Certain success factors are teamwork, better communication, project management, information sharing, and consistency. *Figure 8* shows an overview of a prototype Web-based framework, called POPIM (Pragmatic Online Project Information Management), for managing collaborative product development projects within an extended enterprise environment (Huang, Feng, & Mak, 2001). The framework provides a common workspace for geographically dispersed project team members to communicate, share, and collaborate on a project through online access to the most up-to-date project information. As a result, a high-level data consistency can be maintained, and experience and insights can be accumulated to form the knowledge base. In addition to standard project management functionality, such as defining work structure breakdowns, determining work schedules, teaming up with specialists, and allocating resources, POPIM incorporates workflow management (including dependency management) and deliverable management (document management if documents are considered as one kind of deliverables). Individual members have their personalized accounts according to their skills and roles/responsibilities in a project. A project team and its members may maintain their own journals/records. More application-specific functions, such as product design review and engineering change management, can be implicitly performed through online document forms.

Interoperable Web Applications

Web applications are usually developed for human users to use with Web browsers. Some Web applications have been developed in such a way that they can access each other with little or without human intervention. This type of Web application is considered as interoperable. For example, an application server and a client are interoperable. The client is able to initiate or terminate the server. More importantly, the server and the client are developed in a way such that they can exchange information when they are operating in a mutually understandable way.

Figure 8. Managing a Product Development Project over the Web



Source: Huang, Feng, and Mak (2001)

However, such mutual understanding is not guaranteed between individual Web applications. The reason is that participating Web applications in a project are usually developed by third parties or by the same developer but at different times. At the time when a Web application is developed, other Web applications may not exist or are still unknown for their existences. Therefore, they are not developed to provide “plug and play” type of mutual interoperation.

Considerable efforts have been made to provide a standard for developing interoperable Internet applications. Three of the most popular distributed object paradigms are Microsoft’s Distributed Component Object Model (DCOM), OMG’s Common Object Request Broker Architecture (CORBA), and JavaSoft’s Java/Remote Method Invocation (Java/RMI). The standards for distributed computing only provide specifications regarding the computational feasibility in

terms of the format of information and control exchange between applications. They do not deal with the technical contents of the exchange. Both the formats and contents are of great significance. In the area of distributed artificial intelligence, KIF (Knowledge Interchange Format) has emerged as a format for KQML (Knowledge Query and Manipulation Language) arguments. In the area of product design and manufacture, STEP (standard for the exchange of product model data) is being developed and adopted by individual participants as their internal formats for representing product, process, and resource data and also their results.

As far as the contents of exchange messages are concerned, there has been effort in developing engineering ontologies. This effort focuses on defining formal vocabularies for representing knowledge about engineering artifacts and processes. These vocabularies specify the assumptions underlying the common views of such knowledge.

However, the majority of existing Web applications in the field of product design and manufacture are not developed as being interoperable. This has been highlighted by early experiments such as CyberCut and MADEFAST. CyberCut is an extension of the Integrated Manufacturing and Design Environment (IMADE), developed at the University of California, Berkeley, into a distributed agent environment on the Internet (Smith & Wright, 1996). Another illustrative example system is MADEFAST. It was an early example of a new and rapidly growing genre of projects that use the World Wide Web (WWW) extensively for collaborating and achieving results. The basic idea behind the MADEFAST project is that an engineer would have access to a powerful workstation for recording designs, sketches, memos, meeting notes, etc. This workstation is also connected to the Internet, where it has access to the shared MADEFAST project pages posted by all participants, as well as tools and services.

Most participant systems included in these CyberCUT and MADEFAST experiments were developed by third parties or by the same developer at different times. Therefore, they are not interoperable. Further processing is necessary. One solution is to introduce the concept of agents that wrap up Web application, even stand-alone applications, so that they can be interoperable. Agents are usually attached to the corresponding Web applications on the server side but downloaded to the client side. Such downloaded agents connect the clients to the corresponding Web applications. Frost and Cutkosky (1996) and Smith and Wright (1996) explained how individual agents work and how they work as a community. The authors are further extending the concept of intelligent agents in the context of workflow management (Huang, Huang, & Mak, 2000a).

Web Applications for Group/Team Work

Significant progress has been achieved in developing and applying support systems for group or team decision making. There have appeared two major research themes. One is generally referred as computer-supported collaborative work (CSCW), and the other is workflow management. The Web technology has been used in both.

The aim of the Web-based CSCW research is to develop a Web-based framework or architecture to support teamwork or group decision making rather than individual decision support systems (DSS) for solving particular problems. The participants in these frameworks are usually human members of a project team. Much of the decision making is accomplished by the individual participants, with or without the help of computerized DSS. One example of Web-based CSCW is GroupSystems Web (Romano, Nunamaker, Briggs, & Vogel, 1998). It is an HTML/JavaScript Web-based group support system. It provides an environment for group coordination and a suite of collaborative tools. The environment builds upon the GroupSystem concept, which provides a computer for each participant, software for each task, a public screen to focus attention, a network to share information, access to external data at anytime, at any place supports and extends that concept to provide support for distributed collaboration.

The research on workflow management seems to involve not only human participants but also software systems. Systems are able to initiate and terminate by themselves. In contrast, participants in CSCW are human users who may be assisted by computer systems, not the software participants. In a workflow model, participants, whether humans or software, are represented as nodes and the flow of work as edges. The flow of work includes the flow of data and the flow of control. WebWork (Miller, Palaniswami, Sheth, Kochut, & Singh, 1997) is an example of a Web-based workflow management system. It provides the command, communication, and control for the individual tasks in the workflow. WebWork implementation relies solely on the Web technology as the infrastructure for the enactment system. It supports a distributed implementation with multiple Web servers. It has been developed as a complement to its more heavyweight CORBA-based counterparts with the goal of providing ease of workflow application development, installation, use, and maintenance.

Although software systems can be participants in Web-based collaborative workflow management systems, they can be operated manually by human users or automatically operated by other systems. In the latter case, the software participants become interoperable agents as discussed in this chapter. The authors have proposed an approach where participant systems are represented

as intelligent agents and their interrelated activities are controlled and scheduled by flows of the work (Huang et al., 2000a).

Enterprise Portal for Collaborative Design Review: Case Study

The business process of the case study in this section is that of collaborative design review — a typical subprocess of the CPD process. The resulting Web-based framework — CyberReview — can be considered an EBS that includes a number of facilities for supporting decision activities involved in CDR. If these facilities are themselves considered individual EBSs, then CyberReview becomes an enterprise portal for CDR.

The “Design Review” Business Process

Design review (DR) is a vital control point for any design project to transit from one stage to another in a critical enterprise business process — the product development process. Its purpose is to evaluate the design in terms of costs, quality, and delivery; to ensure that the most suitable knowledge and technology are incorporated into the design; and to resolve possible problems instead of passing them downstream.

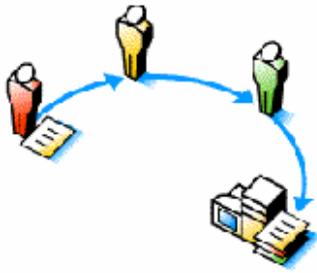
DR is itself a business process that can become very complicated. A team is usually involved and tasked with the evaluation of a design at a certain stage or throughout the process. The team consists of members from multiple disciplines. Some members represent lead users (key customers), some represent core (key) suppliers, and others may come from various functions and units of the organization. In addition to specialist disciplines, the members are typically dispersed geographically.

Traditionally, DR is conducted in a sequential manner, as shown in *Figure 9a*. In the sequential design review practice, the design team initiates the review process by submitting a package of design documents. This package is then circulated among the members of the DR committee one after another. Once all the members finish reviewing all the design documents, a review meeting is organized. This process is usually very tedious and the review cycle time is very long, becoming very inefficient especially when some external members, such as key customers and suppliers, are involved from other geographical regions.

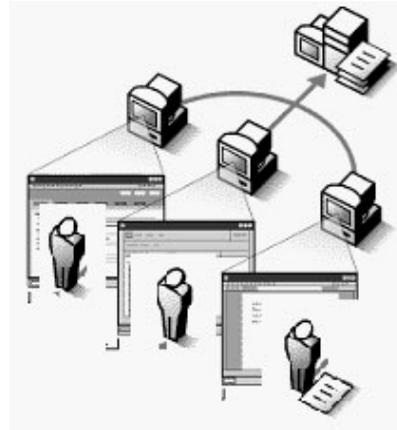
Ideally, members of the DR committee should conduct their own evaluations in parallel to each other. The parallel execution of DR activities is able to reduce

Figure 9. Sequential vs. Parallel Design Review

(a) Sequential design review



(b) Parallel design review



the DR cycle time and thus to improve DR efficiency dramatically. However, this is only possible within an appropriate environment or infrastructure. One method is to make multiple copies of the DR documentary package and circulate them simultaneously to the committee members. This approach creates an excessive amount of paperwork and causes significant difficulties in collating the individual reviews. Naturally, an alternative that is more environmentally friendly and operationally more efficient is to take advantage of the information technology (IT) in general and the Web technology in particular.

Recently, there have been reports on using Web sites to serve as central hubs for members in the DR team to share design documents. Undoubtedly, this simple approach potentially leads to significant improvements in DR practices. The research reported in this chapter has a more ambitious aim to develop an overall methodology for enabling a more efficient and effective design review system in the new product development process and to demonstrate the framework through a prototype Web-based platform on the Internet/intranets using Web technology.

STAR: Systematic Theory for Axiomatic Design Review

Axiomatic design was originally proposed by Suh in the 1980s and formulated as a generic theory of axiomatic design, as demonstrated systematically in Suh (1990). In the theory of axiomatic design, Suh (1990) defines design as the mapping process between the functional requirements (FRs) in the functional

domain and the design parameters (DPs) in the physical domain. Conceptually, the design process can be interpreted as a process of involving choosing the right set of DPs to satisfy the given FRs.

With the same convention of DPs and FRs, we can extend the theory of axiomatic design into a systematic theory for axiomatic design review (STAR) by reversing the direction of mapping between them. In STAR, the mapping is from the DP domain to the FR domain. The establishment of STAR contributes to the scarce literature on design review (DR). The ad hoc DR practice (Ichida, 1989) can now be guided in a systematic way. Thus, such systematic design review practice is more likely to meet the requirements imposed by the ISO 9000 quality standard where design review is mandatory (Schoonmaker, 1996).

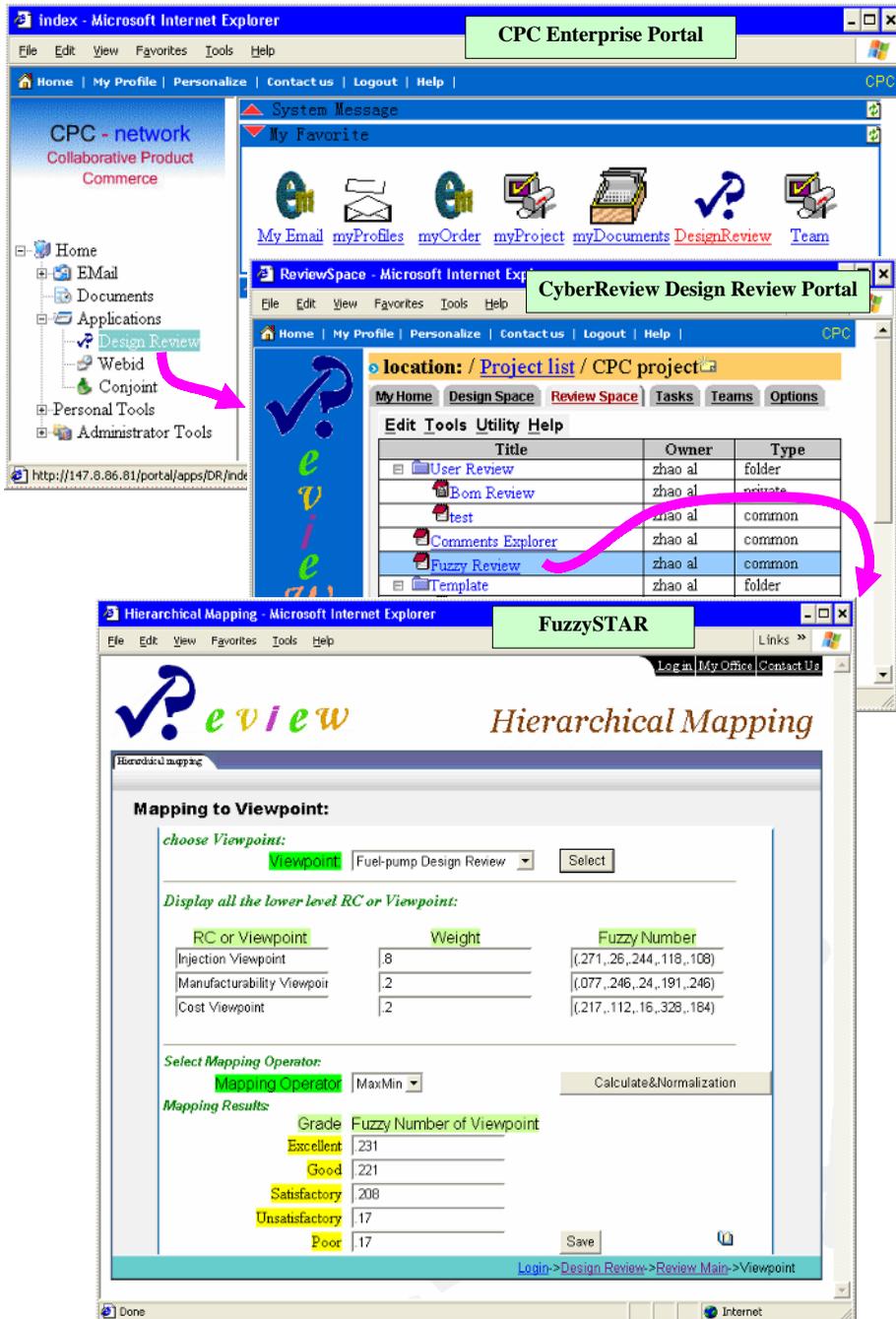
In addition, STAR provides a systematic DR framework for developing computerized (Web-based) decision support systems. This is a significant addition to the PDM (product data management) technology, where DR has traditionally not been treated as heavily as engineering change management (ECM). Based on STAR, Huang (2002) has presented a proof-of-the-concept Web-based application called CyberReview, which can be deployed to form an enterprise sub-portal to support DR activities.

Following previous theoretic investigation and preliminary development, we have fundamentally redesigned and developed the CyberReview system recently. Improvements have been made in two main directions. One is related to the techniques in which the system is implemented. This time, our do-it-yourself components, such as TreeView and Menu, have been extensively applied. The main advantage of this approach is to reduce the cost and cycle time drastically in developing electronic business solutions. The development in this direction is beyond the scope of this paper. The next section will present a brief overview of the newly designed CyberReview.

CyberReview: Enterprise Portal for Collaborative Design Review

As shown in *Figure 10*, CyberReview is deployed as a sub-portal of an enterprise's CPC (collaborative product commerce) portal, which is part of the enterprise portal. After the DR project is selected, the user will be presented with the user interface that includes multiple tabs, as shown in the lower part of the figure. They act as the navigation bar, reflecting the workflow of DR within the STAR framework. The components of the CyberReview are briefly explained next.

Figure 10. Overview of CyberReview



Another typical form of design review is to ask members of the review team to fill in same forms, either online or offline, and then the results are collated by a coordinator. These reports are public or common in the sense that all members must complete them regardless of their roles and expertise.

Finally, a design is often reviewed by various specialists, who normally follow their own review methods specifically developed from their disciplines and produce specialist review reports. Some of these reports are dynamic online documents and some are static offline documents, depending on whether the specialist decision support systems are Web based or not. Normally, specialist review reports are private in the sense that only the specialists of the relevant disciplines have access to them.

Team Explorer for User and Role Management

Generally speaking, there are two groups of professionals involved in design review: the design team, who produces and publishes the designs for review at the enterprise DR portal, and the review team, who obtains the designs from the portal to conduct a review. The memberships of these two teams may overlap to varying extents depending on specific situations of a company. With user role management, their access to relevant facilities is controlled automatically. The third role is that of coordinating design review activities, whether this is done formally by appointing a DR coordinator or implicitly by one member from either the design team or review team. The Team Explorer provides facilities for establishing these teams and defining the roles of individual members in the DR process.

Task Explorer for Project Management

The Task Explorer basically provides facilities for project management, for the project manager or coordinator to plan and manage the activities and resources involved in the design review process, in particular, for establishing the review committee, defining design documents, and preparing review documents. It links the Design Workspace, Review Workspace, and the team responsibilities and roles. The Task Explorer also gives a good overview of the progress of the DR project in the execution stage.

Design Explorer for Design Workspace (DW)

The Design Explorer provides a set of facilities for manipulating the Design Workspace of the STAR framework. Basic facilities include upload and download mechanisms for the design team and the review team to deal with design documents under review. The Design Workspace (DW) provides a repository for archiving design objects in the form of digitized documents related to one design project. Such documents are further classified into offline static and online dynamic. Static offline documents are those files produced by proprietary software systems uploaded onto the CyberReview database. Dynamic online documents are themselves dynamic Web pages whose contents are connected to the CyberReview database or those of the proprietary Web applications.

One of the examples of the dynamic online documents is a Web application for manipulating the product structure in the form of Bill of Materials (BOM). Such a BOM tree is dynamically constructed from the data in the back-end database. The BOM Explorer is itself an independent EBS and can be used in other high-level EBSs such as design change management. In addition to the fact that dynamic online BOM of a product is itself a document for design review, the BOM Explorer is itself a very special representation of the Design Workspace. VRML files, comments, and reviews may be directly related to BOM items.

Review Explorer for Design Review Workspace (RW)

The Design Review Workspace archives the templates of design review reports. The Review Explorer provides facilities for uploading and downloading, even designing, these templates. Similar to design documents under review, review reports can also be classified into static offline and dynamic online.

DR activities take place in several forms, which require different review report templates. For example, DR may take the form of free discussion within an electronic forum, where a reviewer selects a design object (document), creates one or more threads of discussion, and presents his/her initial comments. Other reviewers may follow up the discussions along the existing threads or create new threads of discussions. The Comments Explorer provides dynamic online facilities for this purpose.

Another typical form of design review is through meetings among the review team members. The Meeting Explorer provides a set of dynamic online facilities to support holding review meetings for both the chairperson (project manager) and the team members before, during, and after the meeting.

General Procedure of Using CyberReview

The general procedure of using the CyberReview system follows that of *Figure 3*. The following main activities are involved:

- With the help of the review coordinator, the project manager establishes a review team or committee, specifies design documents to be included for review, and prepares review documents (pro forma and procedure).
- The design team uses the Design Explorer to upload the desired design documents (including 3-D drawings in the VRML format) onto the CyberReview repository.
- Individual members in the review committee use the Comments Explorer to carry out their reviews by submitting comments and suggestions to the CyberReview database. This is generally asynchronous.
- With the help of the Meeting Explorer, a review meeting is called upon to resolve the comments from individual members. This is generally synchronous.

Summary

Whether we are developing or applying EBSs to support CPD activities, we need to identify and group these activities at an appropriate level significant enough to justify the development efforts or to maximize the application effectiveness and efficiency. Although standard methods exist in business process management and project management, exactly how to use such methods remains an art and requires great care specific to the problem domains.

With the emergence of more and more EBSs on the software market and the introduction of EBSs by more and more companies for their product development decision activities, the establishment of a Web portal for these EBSs becomes more relevant and essential. The resulting effectiveness and efficiency of having a central portal/hub for all EBSs for CPD exceed the simple sum of putting them together. The difference becomes more evident if the design workspace is shared without compartments.

However, a common design workspace without compartments does not come without technical or disciplinary restrictions. In fact, all the Web-based systems mentioned in this chapter have not yet overcome their technical limitations of becoming interoperable Web services. In addition, individual EBSs dedicated to

different groups of decision activities will continue to have their own working memories. Great care is needed to capture the interfaces between different groups so that compartmentalized working memories are somewhat interrelated.

While great challenges exist in order to break down the electronic compartments between EBSs, the developments, as they have been, are offering tremendous benefits and advantages over stand-alone systems or platform-specific networked systems. Among many advantages widely lauded, the following deserve further mentioning to conclude this chapter. Firstly, with client-server architecture, both Web-based design services and their users can be geographically distributed anywhere in the world as long as they are available on the Internet. This suits well with collaborative product development, where team members often work at different localities and on different shifts.

Secondly, Web applications are accessible openly and concurrently 24 hours a day throughout the world. Such open accessibility reflects the ready availability of specialist skills and knowledge required in collaborative product development.

Thirdly, as long as the user has the use of an open standard Web browser in a client on the Internet/intranet, he or she can have instant access to any Web-based design tools. Both the client and the server communicate with each other using a standard HTTP (Hypertext Transfer Protocol), regardless of their hardware configurations and operating systems.

Fourthly, installation, maintenance, and upgrading are no longer necessary on the client side. These activities are accomplished on the server side by the service providers. Installation is automatically achieved during the downloading process when an access is made to a Web site.

Fifthly, Web applications have the same performance as stand-alone systems in terms of functionality, interactivity, and usability. This is owing to the multimedia capability and client-side scripting/processing of the Web technology.

Sixthly, Web applications can perform faster than conventionally networked servers because some computation is performed locally on the client machines rather than remote machines.

Seventhly, unlike stand-alone systems where only single users can gain access at a time, Web applications can be accessed by multiple users at the same time. This truly creates a concurrent engineering environment, where product development activities can be carried out in parallel.

Eighthly, Web applications possess greater scalability. This can be easily understood using the three-tiered architecture. Web applications can either share the same data source or have their own data sources at the database tier. The server components of the Web applications can be freely deployed without affecting each other. The client components (Web pages) can be arranged (scaled up) as desired.

Finally, when the Web is used for information management, changes can be posted on the network, thus allowing users in remote locations to have instant access to these changes. A dynamically generated Web page that reports any relevant information to the manufacturing engineers, either on request or by notification, could drastically reduce the “search” time. Furthermore, there is no need for the user to know explicitly how the data is transferred in the system.

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Chapter IV

Collaborative Engineering

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Abstract

This chapter introduces the importance of information technologies for the integrated product and process development within the framework of manufacturing excellence models. It argues that the success of the interaction between different activities holds on the necessity of an appropriate product data quality. The authors present a description of the evolution of concurrent engineering to extended enterprise collaborative engineering and introduce basic mainstays where computer tools and technologies enabling virtual workgroups will suppose a key element for these environments. The expansion of enterprise architectures using extended and virtual models is possible due to the advances of communication tools and the capabilities of computer-aided tools that heavily depend on the digital product representation. It is expected that focus on the product data quality not only will solve the intrinsic problems related to CAD model structure data exchange but also will simplify the integration of downstream applications in the collaborative engineering design chain.

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Introduction

Product development is a key activity for enterprise survival and competitiveness. This process must be agile and efficient in order to provide enough flexibility to adapt products to a continuously changing market. Most of new product development methods are based on empowering the role of design and shortening the development cycle of new products. Digital tools like CAx and product data management (PDM) systems are key elements in this strategy. They allow us to experiment with many alternative solutions, providing better high-quality products in less time which are inexpensive to produce. Shortening the development cycle and lowering costs are some of the advantages of employing digital mock-ups and simulate manufacturing in a virtual environment.

A complete digital representation of the product and its manufacturing process allows us to carry out complex simulations, avoiding the construction of physical prototypes and detecting bottlenecks in the manufacturing process. In this way, both an important time reduction in the whole development process and a better quality are obtained, as more design alternatives can be explored.

However, this approach is not exempt of problems because it is necessary to transfer product data between different software applications. This introduces the data exchange problem because data can be degenerated or even lost during exchanges. In this context, product data quality is becoming a key issue to guarantee a true integration among actors defining the product development process.

Beyond Concurrent Engineering to Collaborative Product Development

Looking into the origins of the problem, it is well known that product development has suffered an enormous evolution over the last two decades. The appearance of concurrent engineering (CE) was a milestone in simultaneously lowering product cost, increasing product quality, and reducing time to market. Concurrent engineering was born as an initiative of the US Department of Defense. In 1982, the Defense Advanced Research Projects Agency (DARPA) began a program with the objective of improving product development. As a result of this program, Winner, Pennell, Bertrand, and Slusarczuk (1988) first defined the term *concurrent engineering*:

“Concurrent Engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacturing and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life-cycle from conception to disposal, including quality, cost, schedule, and user requirements.”

After this project, DARPA started a five-year program, the DARPA Initiative in Concurrent Engineering (DICE), aimed to incorporate this methodology in the US military industry. As part of this initiative, the Concurrent Engineering Research Center (CERC) was founded at West Virginia University in the US. As a result of this work, Cleetus (1992) proposed another definition for CE:

“Concurrent Engineering is a systematic approach to the integrated and concurrent development of a product and its related processes, that emphasizes response to customer expectations and embodies team values of cooperation, trust, and sharing in such a manner that decision making proceeds with large intervals of parallel working by all life-cycle perspectives, synchronized by comparatively brief exchanges to produce consensus.”

At the end of 90s the quest for reducing costs led to the progressive outsourcing of design tasks to suppliers. This movement brought suppliers into greater involvement in design and product technology responsibility (Gao, Manson, & Kyratsis, 2000). The most advanced industries, like the automotive, aeronautical, and aerospace ones, soon adopted this trend. Automotive maker Chrysler pioneered the development and the use of the extended enterprise concept. It means working closely with the supply base in a teamwork atmosphere of cooperation based on trust, communication, and partnership, where the workgroup usually is geographically dispersed and advanced tools support communications.

In the last years, new enterprise models appear to exploit modern high-performance computer networks. In this context, the concept of extended or virtual enterprise (Goranson, 2003), with its sharing of data, costs, skills, and technology, allows this new kind of enterprise to introduce products into the market that previously could not deliver individually. The European Society of Concurrent Engineering (*Glossary*, n.d.) defines a virtual enterprise as a:

“distributed, temporary alliance of independent, co-operating companies in the design and manufacturing of products and services. Such a complex organization makes use of systematic approaches, methods and advanced

can be found in that the new information technology environments demand new organizational capabilities to obtain competitive success. Frequently the fundamental origin of this problem is due to a strategy of the company that is unclear or because the new barriers have not been contemplated.

Many authors (Davenport, 1993; Kaplan & Norton, 1996) agree in that, to resolve this lack of understanding, managers should be able to transmit the strategy of the business unit towards the lower management level, defining some specific strategic objectives that could be summarized in actions that will be supported in new techniques or technologies. In the opposite way, inferior levels should be able to guarantee that all the efforts carried out in the operative part are completely aligned with the strategy that will address future actions of the company and that will establish the new medium- and long-term investments regarding employees, processes, and technology.

In the application field of new information technologies, strategy will be “*every collection of rules that will assure a good decision made in each moment for its implementation and development, in order to reinforce its alignment with the global objectives of the organization.*”

In a general way, we can say that, basically, strategic management emphasizes three environments: the *strategic analysis*, which implies the investigation of the mission, the values and the objectives of the company, as well as the study of the environment and the resources; the *formulation of the strategy*, which should be carried out at corporate, business, and functional levels; and the *implementation of the strategy*, where it is necessary to study the organizational structure of the company, their capacities, planning, and control.

For the development of the strategy, carried out by managers, it is convenient that it will include an entire series of associated performance measures or metrics that will allow us to assess if the strategy has been clearly defined and formulated and if it is being implemented correctly.

For example, Prasad (1996) proposes a global system of strategic metrics for managers that will allow them to evaluate this competitiveness improvement and that should be later particularized in specific metrics for each process it is required to innovate.

When establishing this strategy it is necessary to consider the interactions of new technologies. Therefore, it is necessary to define new management models that will facilitate the integration of different activities with their diverse objectives, taking advantage of the new tools, to provide a new perspective for strategic management.

Summarizing, managers should adopt a model that will allow them to identify the predisposed improvement areas to increase competitiveness. This model will require performance measure systems that will identify which level of innovation

technologies for increasing efficiency, and is enacted by the means offered by recent Information and Communication Technologies.”

Integrating the virtual enterprise paradigm and the methods of concurrent engineering, a new concept named concurrent enterprise arises. Thoben and Weber (1997) proposed the following definition:

“The Concurrent Enterprise is a distributed, temporary alliance of independent, co-operating manufacturers, customers and suppliers using systematic approaches, methods and advanced technologies for increasing efficiency in the design and manufacturing of products (and services) by means of parallelism, integration, team work, etc. for achieving common goals on global markets.”

However, companies have had problems adapting new technologies while trying to transform the product development process. Although they have spent many millions automating the design activities and the manufacturing ones they haven't had success in achieving their strategic goals.

With this negative experience, companies began to understand that one of the weaknesses was the lack of a link between their main objectives and the innovation processes performed, and the need for a survey to explore the origin of this rupture.

The vision of the company through the added value chain allows managers to develop the processes management view, breaking up therefore with the traditional models. Processes management reinforces the models of managerial administration because it allows us to identify those that should be continuously improved to satisfy the client's requirements. Furthermore, processes management makes the connection of the main objectives possible with the innovation actions that can strongly influence in strategic processes, such as those of creation of value processes or support processes.

Within this context, it is clear that all the actions focused on technological and organizational innovations for the product development process should come from the company's strategic planning since this is one of the processes that exploits the competitiveness of the company, optimizing their contribution to the added value chain (strategic planning determines how one wants to compete in a temporary horizon and it can be, basically, either being leaders in costs or differing in the product).

As we have already mentioned, companies have not known how to adapt the new technologies to the organization to achieve these strategic objectives. The reason

is necessary for the selected processes so it will be aligned with the global strategy.

Therefore, it is necessary to survey different company activities from another point of view, so that the contribution of each one and how they interact during product development is reflected in the process. This approach should be able to offer us key information in understanding the importance of integration of activities.

Manufacturing Excellence Models

Excellence models with a general approach try to evaluate if the companies are implied in the encouragement of the total quality and to detect to what extent. Reference models make an effort to unify approaches, avoiding the proliferation of total quality management models, so that companies can be compared to this model and check out if they are achieving quality requirements.

On one hand, there are models such the Malcolm Baldrige Quality Award (National Institute of Standards and Technology, 2003) and the EFQM Model (European Foundation for Quality Management, 2003), which result from multiple iterations carried out in studies and proposals by academic institutions and governments. These models consider the different existent interrelations inside and outside of the company that continuously feed back and converge, a consequence of their maturity through time.

On the other hand, there are the proposals of particular aim excellence models, headed to manufacturing companies, as developed by the Society of Manufacturing Engineers and by the Next Generation Manufacturing project (NGM).

These excellence models clearly reflect the new problem of information technologies in all its extensions, not only from the technological point of view but also as support tools for the innovation of products.

Information technologies have posed a second industrial revolution, deeper and wider than the steam machine. The competitiveness, and therefore the survival of the existing company, is determined in good measure by its adaptation to this changing environment and the advantages that these new tools bring.

In 1985, the Computer and Automated Systems Association of the Society of Manufacturing Engineers (CASA/SME) published its integrated vision of the company (computer-integrated manufacturing wheel) that symbolized the general structure of an automated company. This model, which was generally accepted, demonstrated that production had entered into the new era of information technologies, where computers would be fundamental to manage the manufacturing company.

However, this model did not articulate topics as important as the need for simplifying the processes before its automation or also the interaction of the company with its clients and suppliers. Therefore, a new model was developed, looking for the integrated management and overcoming the existing barriers between design and production. The new manufacturing enterprise wheel (Computer and Automated Systems Association of the Society of Manufacturing Engineers, 1993) upgraded the previous vision of the manufacturing company, based only on the internal integration and automation and stressing the key role of the client. It is, essentially, a framework that describes six critical success factors (client, people and teamwork, systems and knowledge, key processes, resources and responsibilities, and the manufacturing infrastructure) belonging to different levels that will allow the company to achieve a competitive production.

Somehow the wheel defined by CASA/SME (1993) guided the Next Generation Manufacturing (NGM) project (Agility Forum, Leaders for Manufacturing, and Technologies Enabling Agile Manufacturing, 1997), which provides a framework to assess the business of a manufacturing company and to develop strategic answers to gain success in the next-generation companies.

The NGM framework uses a hierarchical format that, in the first place, identifies the global drivers of the new marketplace, forces that guide the competitive environment of the future and that exist independently of the actions of any individual company. These guidelines are the readiness and location of information, the quick changes in technology, the access to technology, the globalization of markets, the correspondence between experience and their remuneration, the environmental responsibility and the limitation of resources, and, finally, the increment of client expectations.

From these guidelines derives a set of attributes that next-generation companies and enterprises must possess. A series of barriers and attendant dilemmas are then identified that must be overcome to achieve the NGM attributes. Key enablers to overcome these barriers are then defined as imperatives. From the imperatives arise the specific action recommendations that can be acted upon to move toward the next generation.

The NGM project identified a set of generic enabling practices and technologies that were critical for achieving the NGM attributes and resolving the NGM dilemmas. They clustered these enablers into 10 high-leverage imperatives, as follows, grouped within the four elements of the NGM model:

- *people-related imperatives*: workforce flexibility and knowledge supply chains

- *business-process-related imperatives*: rapid product/process realization, innovation management, and change management
- *technology-related imperatives*: next-generation manufacturing processes and equipment, pervasive modeling and simulation, and adaptive, responsive information systems
- *integration-related imperatives*: extended enterprise collaboration and enterprise integration

This framework is not only a practical approach to the present reality of manufacturing companies but also a reference for the interaction between key processes, such product development, and those that will allow the collaborative engineering vision.

Product Development Continuous Improvement

As we have exposed, new excellence models are driving companies on the way to competitive positions through the integration of all the areas, processes vision and the development of strategic planning integrated systems.

If we pay attention to the basic added value chain proposed by Kaplan we can detect that there is a process that requires special attention, the innovation process, which represents, for manufacturing companies, a key element where the company can add more value to the created product.

In order to complete this process successfully, companies have to think about the goal of continuously reducing development times and costs and increasing product quality. NGM provides, therefore, an appropriate framework for improving the product development process through the imperative rapid product/process realization and its relationship with the other imperatives, specially modeling and simulation, adaptive and responsive information systems, extended enterprise collaboration, and enterprise integration.

This means that the transformation of the product development process should be done through information technology implementation. Although a new processes-oriented vision focus on product development will be necessary, it is not enough to regularize new information-technology-based environments.

But this transformation requires a strategy aligned with the excellence models, which have not received enough attention, and several key elements need to be focused on:

- An organizational model that should be capable of supporting those strategic objectives. A model that contemplates the whole product life-cycle, from client product requirements and the first conceptual ideas until its retreat (Wang, Shen, Xie, Neelamkavil, & Parsadani, 2002).
- Consideration of the human resources integration while implementing the new integrated product development organizational structures, bearing in mind the new teamwork techniques.
- Adoption of new product design methodologies and theories. They allow us to consider integrating suitable product production aspects as soon as other life-cycle activities, assuring that the client's voice drives the whole design process (Smith & Blanck, 2002).
- Computer support systems that necessarily ought to include product development tools and those ones that could facilitate the negotiation process, exploiting current information technologies.

These key elements, which should drive the transformation of the product development process, constitute the basis of continuous improvement through concurrent engineering philosophy and deserve our attention on how to align them with concurrent engineering best practices.

Concurrent Engineering Principles

The implementation of the concurrent engineering philosophy, and consequently collaborative engineering, implies a great cultural change within the company, and it should be carried out cautiously. The maturity of concurrent engineering practices can hardly end up efficient if they aren't preceded by correctly planned implementation, aligning the objectives of the product development process improvement with the strategic objectives.

All the exposed ideas bring us to a newer concept of concurrent engineering that observes the aspects approached during our exhibition. Its definition goes beyond those carried out initially and seeks to highlight the improvement in the innovation of products and of processes that can be achieved with the adoption of this new philosophy:

“Concurrent engineering supposes the integration of the product development process through teamwork with all the areas involved in its life cycle. With this aim, product design methodologies and tools are used to allow a regular exchange of the produced information related to the

product and to allow internal and external collaboration, and that they facilitate that decisions making is carried out in a synchronized way and consensus getting this way the improvement of terms, quality and innovation required by the client.”

With this definition it is important to define a series of elements that could constitute concurrent engineering basic mainstays. The correct unfolding of these elements, customized for each company, will provide an appropriate concurrent engineering environment through which we will assure the success of this new work philosophy.

We consider crucial, as the first mainstay, to define the new design and manufacturing process clearly, which is not usual, especially in small and medium enterprises. In order to achieve this aim, processes and activities modeling is fundamental because it can provide a common working framework to begin to implement concurrent engineering. Drawing a model of company processes forces us to obtain a consensus on the objectives, eases the communication, and constitutes a tool for the analysis and the design of new processes. Obviously, modeling is a tool used for continuous improvement, and the proposed changes can be introduced before being put into practice, helping us to evaluate the impact of product development process modifications.

However, product development process modeling is not enough; we also need to evaluate certain characteristic activities to be able to manage the innovation process and to control and track the new process, determining, therefore, the obtained improvements. This means that it is necessary to define an entire performance measures system that will help us to control the new process and to qualify and quantify the improvements of the process.

As teams are the core of concurrent engineering, it is necessary to define them and to adapt them to the new design process, considering all the activities that influence the product life-cycle; they are the second basic mainstay. Teams can be put into practice, setting up formal meetings and using diverse workgroup techniques, where team members can transmit their experience and knowledge, achieving better results.

This knowledge already exists in very small companies that have qualified people with a lot of practice, but usually they don't constitute or formalize these procedures and, therefore, they don't manage this knowledge. Besides, nobody guarantees that these teams are taking the maximum advantage of their potential when not using methods or appropriate techniques for integrated product development.

Consequently, methodologies and techniques focused on improving product design and development constitute the third basic mainstay. There are more than

100 of them listed (Boothroyd, Dewhurst, & Knight, 1994; Pugh, 1991), but some of the most frequently used ones are:

- *QFD (quality function deployment)*, a structured method in which customer requirements are translated into appropriate technical requirements for each stage of product development and production.
- *DfX (design for X)* techniques capture, in a standard procedure, all the factors known to be important in a particular design activity. For example:
 - **design for manufacturability (DFM)**: rules that can ease manufacturing during early conceptual development,
 - **design for assembly (DFA)**: rules that can ease assembly during early conceptual development,
 - **design for environment (DFE)**: rules to achieve a design that uses minimum material and energy at all stages of the life cycle, providing maximum reuse and recycling of products.
- *FMEA (Failure model and effects analysis)*: a procedure to analyze each potential failure mode in a system, to determine the potential effects caused on the system, and to classify each potential failure mode according to its severity.
- *DOE (design of experiments)*: a branch of applied statistics dealing with planning, conducting, analyzing, and interpreting controlled tests to evaluate the factors that control the value of a parameter or group of parameters.
- *Taguchi methods*: a quality engineering methodology, based on the design of experiments, to provide near optimal quality characteristics for a specific objective to improve quality and reduce costs.

We can also lean on computer-aided technologies, CAD/CAM/CAE tools; and other CIM-related tools, together with new communication and information technologies, will allow reducing design and production time. They represent the fourth basic mainstay.

Actually, companies already deal with a great amount of information that needs to be transferred: drawings, data, reports, process plans, work orders, and so on. This can be carried out in many different ways and by diverse mediums, causing a complex management. Those companies that are geographically distributed or that have a technical office with a considerable number of employees who work very closely with a high horizontal and vertical interdependency degree cannot easily centralize this type of information. Therefore, the help of well-defined architectures for an intranet, Internet, and electronic data interchange system

ought to be a prerequisite to work in successful advanced concurrent engineering environments. These systems and their architectures constitute the fifth mainstay.

The accomplishment of these five mainstays, obviously customized for each company, with the empowerment of the computer tools and technologies enabling virtual workgroups will suppose not only a successful concurrent engineering environment but also the first step to collaborative engineering.

Collaborative Engineering Key Issues

In order to cover the strong competitiveness of the global market, companies should be equipped with the ability of effective and efficient communication so that correct information can be transferred to the correct person in the right place and at the precise moment. Besides, during the last two decades, manufacturing globalization has quickly become enhanced and its importance has been increased.

Therefore, since 1980 great efforts have been directed to developing and implementing computer-supported collaborative work (CSCW) systems. A CSCW environment is a set of software, hardware, language components, and procedures that support a group of people in decision-related meetings (Monplaisir & Haji, 2002). CSCW systems usually include software such communication tools, shared computer-aided applications, file transfers, chats, or videoconferencing.

These tools have helped the essence of integrated and collaborative concurrent product and processes development that, from now on, we will refer to as collaborative engineering.

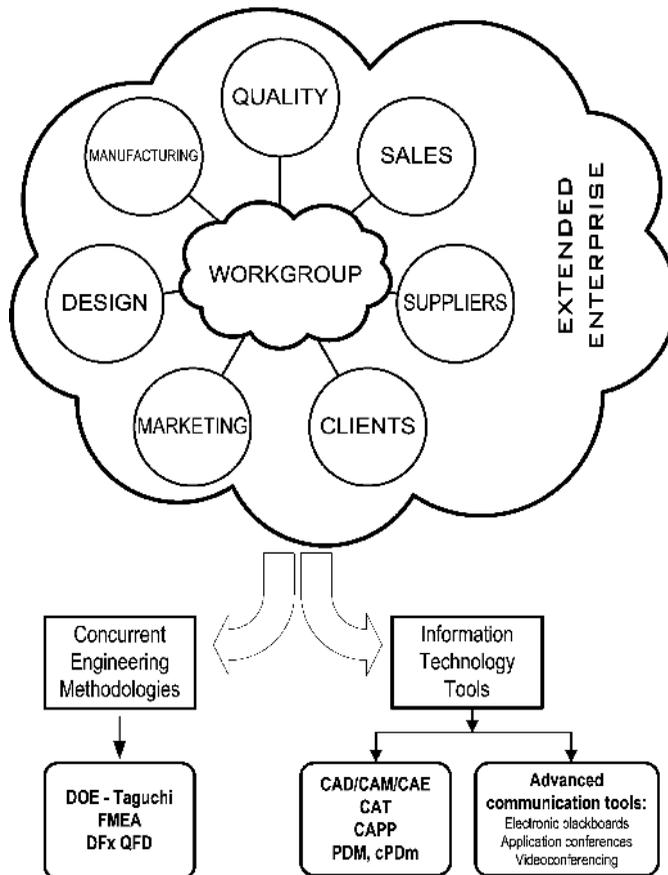
Collaborative Engineering Concepts

We must broaden the scope of concurrent engineering to include the new models of extended enterprise, virtual enterprise, and concurrent enterprise that have been spread during the last decade. The concept of collaborative engineering encompasses both supplier integration and advanced communications tools to cope with the product development process and extends the scope of concurrent engineering. With the intention of widening the scope of concurrent engineering, de Graaf (1996) proposes the following definition for collaborative engineering:

“Collaborative Engineering is a systematic approach to control life-cycle cost, product quality and time to market during Product Development, by concurrently developing products and their related processes with response to customer expectations, where decision making ensures input and evaluation by all life-cycle disciplines, including suppliers, and information technology is applied to support information exchange where necessary.”

In Figure 1 we present a schematic vision of our collaborative engineering model, based on de Graaf’s definition. The central element is the workgroup, usually geographically dispersed, working in the context of the extended/virtual enterprise. Concurrent engineering methodologies and information technology tools support the product and processes development. As in de Graaf’s definition, product life-cycle, customer input, and supplier involvement are underlying elements included in the model.

Figure 1. Collaborative Engineering Conceptual Model



Computer Support for Collaborative Engineering

Collaborative engineering deals with all the mainstays and all the included topics such modeling, teamwork, methodologies, computer support, and architectures. In this chapter we will focus only on advanced communication tools and information technology tools in order to find, finally, what is the inherent problem of electronic collaboration.

Advanced Communication Tools

The heterogeneous enterprise architectures we have presented previously have promoted the development of new Web-based design tools, which combine CAD, PDM, and Web access in a unified environment. These tools are aimed to reduce costs between original equipment manufactures (OEMs) and suppliers sharing a common design platform. Usually this kind of application is built on a three-tier architecture using the Internet as the communication infrastructure. Thus, we have a first tier where a thin client, usually through an Internet navigator, provides the front end to the system. In a second tier, an application server hosts the software application. Finally, the database server, holding the central data repository that stores and manages design data, provides the third tier. This technology also introduces the concept of subscription, where users pay a monthly subscription fee for the service. This approach allows companies to reduce information technology expenses, avoiding buying and maintaining expensive software and hardware. The growing Internet bandwidth is supposed to broaden this technology in the near future.

The first supporting technologies for collaborative engineering we will comment on are communication tools. These tools evolve parallel to the Internet and are fundamental to provide collaboration for a geographically dispersed work team. Here we can distinguish between synchronous and asynchronous collaboration (Deng, Pettersen, Jensen, Bang, & Davidrajuh, 2000), depending whether the collaborative partners are working simultaneously or not. Examples of asynchronous collaboration are e-mail and newsgroups. On the other hand, to arrange a virtual meeting with our partners, synchronous communication tools like whiteboards, videoconferencing, and application sharing are needed. In the context of the extended enterprise, it is usual to find a multi-platform and multi-vendor environment. For that reason, communication standards are an enabling element to real team collaboration. The International Telecommunication Union and the International Multimedia Teleconferencing Consortium have developed several families of standards with this purpose. Thus, the T.120 series of recommendations collectively defines a multipoint data communication service

for use in multimedia conferencing environments. Inside this series, recommendations related to the communication layer are found (T.122, T.123, and T.125). The collaboration layer provides support for both data and audio/video conferences. Thus, recommendations related to data conferencing are:

- T.126: multipoint still image and annotation protocol
- T.127: multipoint binary file transfer protocol
- T.128: multipoint application sharing
- T.134: text chat application entity

The audio/video conferencing part proposes three standards associated with communication bandwidth:

- H.320 for ISDN videoconferencing
- H.323 for LAN videoconferencing
- H.324 for low-bit-rate connections such as POTS

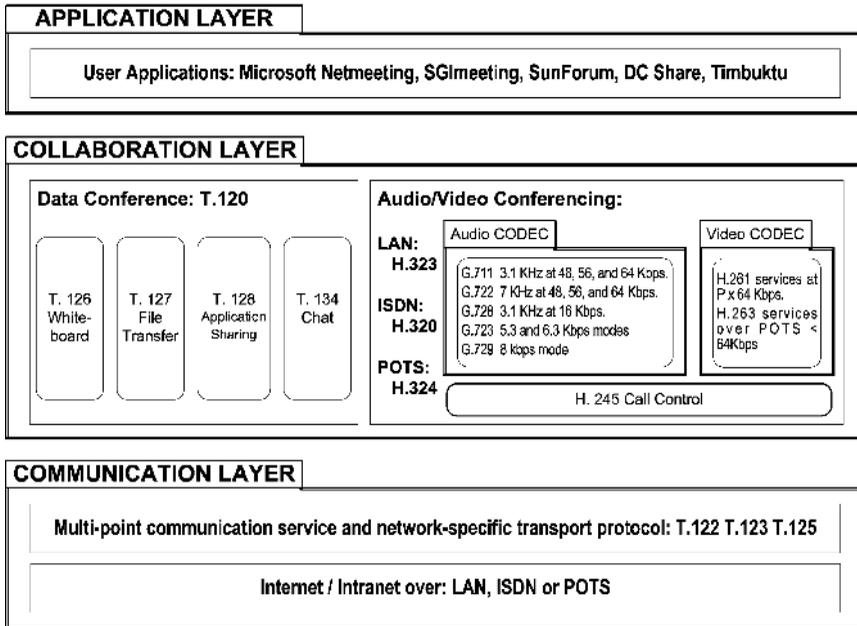
Nowadays, the main limitation for using these tools is communication bandwidth. From a practical point of view, in restricted bandwidth situations, parts of the data-video-audio conference can be redirected to other communication channels; for instance, moving audio conferencing to normal telephone calls and making selective use of the video, which is the most bandwidth-consuming part.

One of the most interesting facts about communications tools is that many of them are free, or their cost is much reduced. So, an imaginative use of them can be very productive. For example, setting up a newsgroup server can be a very cheap way to provide a discussion forum where team work members can ask for help or receive general notifications about the product development process.

Obviously, communication tools are not enough for collaborative engineering. They provide virtual teams the means to discuss and analyze design projects, but there are still several issues to resolve, such as encouraging members' participation, conflict resolution, meeting control, or decision making. The last one, decision making, is critical in collaborative engineering and other fields, and, therefore, decision support systems have been developed since the early 1970s.

Decision support systems (DSSs) are a particular category of computerized information system that supports business and organizational decision-making activities. DSSs are interactive software-based systems and subsystems intended to help decision makers use communications technologies and compile

Figure 2. Architecture of Communication Tools



useful information from raw data, documents, personal knowledge, and/or business models to help answer questions, identify and solve problems, hold up or refute conclusions, and make decisions.

The evolution of DSSs started with a decision tool (Shim et al., 2002) that contained sophisticated database management capabilities (with access to data, information, and knowledge), powerful modeling functions, and friendly user interface. During the 1990s new tools — data warehouses, online analytical processing (OLAP), and data mining — began to be developed for improving DSSs. But it has been with the exponential growth of Internet technology that DSSs have acquired a very important role due to the rapidly expanding volume of real-time data, information, and knowledge. The Web environment has been constituted as a critical delivery platform for the development of Web-based DSSs, which extends its original capabilities and allows the participation of a large number of geographically distributed users. Web-based means that the entire application is implemented using Web technologies, while Web-enabled means that main parts of an application, like a database, remain on a legacy system although the application can be accessed from a Web-based component and displayed in a Web browser.

In particular, Web-based DSSs refer to applications that deliver to a manager or business analyst decision support information or decision support tools using a

thin-client Web browser like Netscape Navigator or Internet Explorer that is accessing the global Internet or a corporate intranet. Computer servers that host DSS applications are linked to the user's computer by a network with the TCP/IP protocol. Web-based DSSs can be communications driven, data driven, document driven, knowledge driven, model driven, or a hybrid. Web technologies can be used to implement any category or type of DSS.

If we focus on the engineering product development cycle, conceptual design is, possibly, the most crucial task. It involves several phases, starting with engineering specifications clarification and followed by the establishment of functional structures of the product, the search for appropriate working principles and their combination, and the evaluation of concept variants against technical and economical criteria (Wang et al., 2002). The conceptual design ends with the phase of decision making, which, as we mentioned before, is critical in collaborative engineering; and, therefore, Web-based DSSs are needed.

When analyzing the implementation of Web-based DSSs, we must take into consideration that we can find several types of distributed concurrent engineering design (DCED) environments depending on the way teams are located and on the way DSSs operate. Huang and Mak (2002) found nine possible combinations of teams and DSSs, attending to the combination of a colocated, local, or distributed team with a stand-alone, centralized, or distributed DSS. The combination of distributed team and distributed decision support system is the most sophisticated mode that has been adopted thanks to Web technologies. The choice can be more complex if we consider that there can be several levels of collaboration depending on sharing final results, sharing decision models, or sharing intermediate results. We must also note that during collaborative design the use of information technologies ought to be coordinated with Web-based DSSs.

Information Technology Tools

Information technology (IT) development has completely transformed product development. New methodologies, specifically oriented toward shortening the development cycle, have been adopted. The growth in simulation-based design tools nowadays makes it possible to analyze the behavior of complex products without constructing physical prototypes. Virtual factory software allows simulating production and detecting bottlenecks early in the factory design phase. These new methods are represented in *Figure 3*. The essential element in this development approach is the 3-D solid model provided by CAD applications. A plethora of downstream applications like CAM, CAE, and many other CAx tools depends on the geometric model.

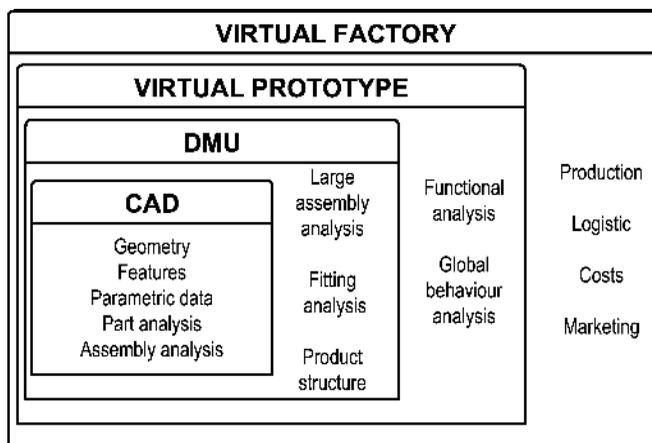
Digital mock-up (DMU) tools are able to manage large assemblies of thousands of parts. In this way, it is possible to detect tolerance and assembly problems early in the design phase. Current DMU applications are able to manage complex products such as a complete airplane representation. However, optimized tessellated representations extracted from the 3-D solid models, are needed to cope with so many parts. Some systems also provide several representations for each part, each one according to a different level of detail (LOD). These tools provide simultaneous capabilities for design collaboration, markup, fly-through, and interference and collision detection.

Virtual prototyping tools go a step beyond. Their objective is to assess product function and operating performance. Virtual prototyping solutions make use of finite element analysis and advanced calculus to predict accurately the operating performance of the product by means of virtual tests. Thus, we can simulate a crash test with a virtual car, analyze its dynamic behavior, optimize aerodynamics with computational fluid dynamics (CFD) applications, and so on.

In the superior stage, virtual factory simulation (Klingstam & Gullander, 1999; Zhai, Fan, Yan, & Zhu, 2002) is used to assess manufacturability and assembly of the product. There are two main types of simulations:

- Discrete event simulation (DES) applications simulate the behavior of entities when an event occurs at a distinct time. This kind of simulation is aimed at material flow simulation, the manufacturing system, and information flow analysis. Usually, time in a DES simulator does not proceed linearly but in irregular intervals.

Figure 3. Advanced Product Development



- Geometric simulation (GS), also known as continuous simulation, proceeds with time linearly in constant intervals and provides a geometric representation of the whole manufacturing system. It is appropriate for 3-D visualization, offline programming of robots, and collision detection during the manufacturing process.

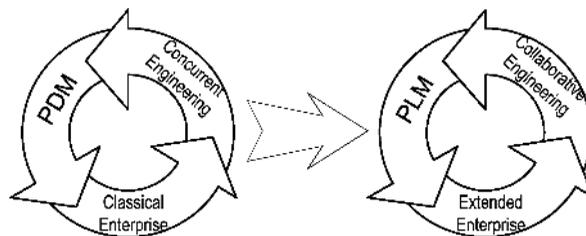
Virtual factory simulation provides significant savings, allowing early detection of manufacturing bottlenecks in the design phase, not under operation.

The other essential element of information technology is PDM systems. Product data management (PDM; Drira, Molina, Nabuco, Rodriguez-Peralta, & Villemur, 2001) is the supporting tool that enables us to carry on these advanced simulations. PDM has evolved from a CAD file manager application in mid-80s to provide sophisticated functions as:

- Engineering data management: providing data vaulting and document management, product structure and configuration management, classification, and search.
- Engineering workflow management: providing project management, engineering change and release management, and communication support.

At present, PDM systems are evolving to take into account Internet, Web-based technologies (Liu & Xu, 2001) and the new extended/virtual enterprise paradigm. This evolution leads to the concept of “product life-cycle management” (PLM; Miller, 2001), which is a broadening of PDM capabilities to support the management of product definition and associated processes in the extended enterprise framework by means of Internet/Web technologies. These kinds of systems are particularly interesting for global companies with facilities located around the world and also for enabling true integration among OEMs, clients, and suppliers in the product development process.

Figure 4. Evolution from PDM to PLM



PLM systems allow us to simplify and unify the information flow, permitting us to operate with data not only coming from CAx applications but also with other data and knowledge generated in all extended enterprise areas. PLM users can have all the updated information related to product structure and its processes, using it for their specific tasks and to generate all the required personalized reports. These systems include modules or subsystems needed during the product development cycle; some of them are:

- design process management module
- engineering changes orders management module
- product configuration management module
- files repository and electronic expedition of documentation

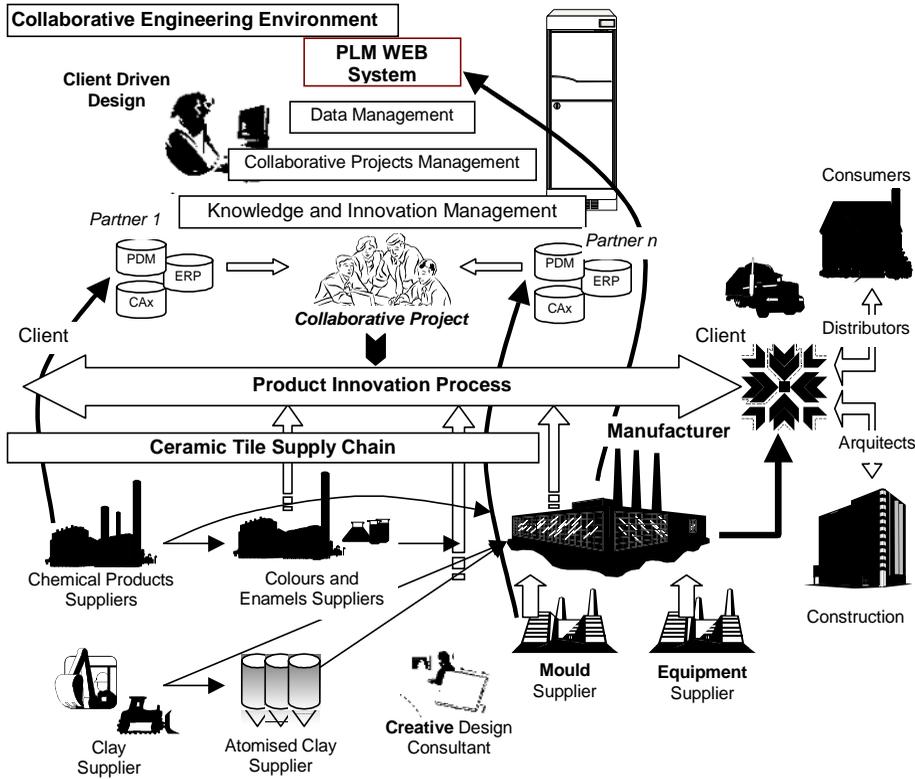
With these services, sharing global information of the product becomes a reality, obtaining, therefore, rich inputs that can have a significant effect on costs, quality, innovation, and competitiveness, which is the competitive advantage of collaboration. Some of the advantages can be:

- Eliminate the search process and retrieving of lost or not well-located data.
- Facilitate the information flow within the workgroup.
- Eliminate the time invested working with old data.
- Provide an active notification system to maintain informing of the members of the team.
- Allow work of geographically dispersed work teams.
- The time of development and the global costs can be drastically decreased.

PLM systems allow us to create, to negotiate, to share, and to reuse vital information of the product and the market in real time. Based in the use of Web technologies, they allow us to connect partners, clients, and suppliers in the design and development process of the product, negotiating all the functions associated with the life cycle that are basic for their existence (collaborative design chain).

Collaboration requires the use of a structure of collaborative data administration implanted in the corresponding databases. The stored information will be visible on the Internet and accessible from any localization for all the authorized people. PLM is, in summary, the infrastructure to get an extended company. These ideas

Figure 5. Collaborative Engineering Process Applied to the Ceramic-Tile Supply Chain



can be exemplified with a specific model of the collaborative engineering process for the ceramic-tile supply chain, which is a very dynamic sector (Figure 5).

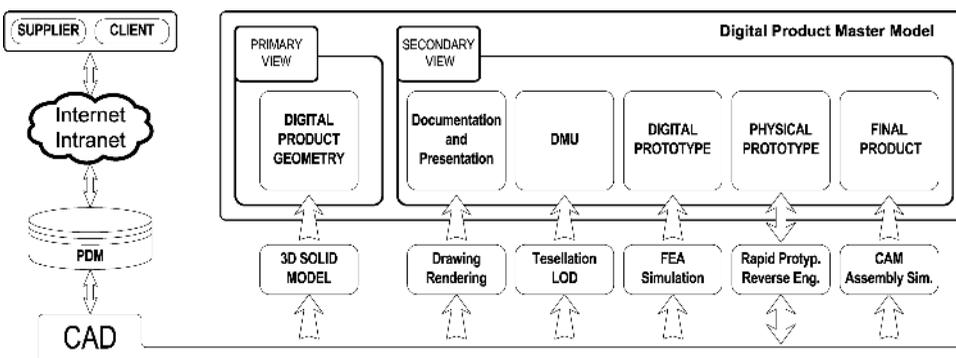
To finish this analysis of collaborative engineering, we must emphasize that the key for all of the product development process is a digital product representation. The next section will study this aspect in depth.

The Problem of Product Data Exchange

CAD and PDM systems are the primary elements for the advanced product development process, as noted in Figure 3. Product data management systems (Drira et al., 2001; Höhn, Steingröver, & Dyla, 2000) supply an infrastructure oriented to provide everybody's need for information in a concurrent engineering

- *Rendering:* This application takes advantage of the 3-D model by means of a surface representation generated by a tessellation process, as provided by the stereolithography (STL) format.
- *Digital mock-ups:* This application usually uses simplified representations of parts obtained by tessellation and implement models with different levels of detail (LODs), specially for visualizing complex structures.
- *Digital prototypes:* The simulation and finite element applications use simplified representations of the primary view for making their calculations. FEA applications need geometry free of small details to proceed with mesh generation. This can be easily accomplished by an appropriate modeling methodology where unwanted features can be suppressed.
- *Physical prototypes:* Handmade prototypes have been replaced with rapid prototyping tools. RP machines make use of a derived model extracted by tessellation from the 3-D solid. The STL format is the industry standard for this purpose. The other application for physical prototypes is CAD data input in styling applications, where 3-D laser scanning devices provide clouds of points that later must be transformed to surfaces and imported into the CAD application.
- *Final products:* CAM and assembly simulation make an intensive use of the primary view. Besides, sometimes it is necessary to make modifications in the original geometry. For example, in mould design, usually nominal part geometry must be deformed to allow injected parts to get the right geometry and tolerances. This requirement introduces additional difficulties because the reuse of the primary CAD model for this purpose depends on the modeling methodology previously used.

Figure 6. Digital Product Model



environment. These systems also cover external partners' access and company security and release procedures. We can distinguish:

- *Product data (and tooling data)*: geometry, DMU, analysis and simulation results, materials, reports, etc.
- *Process data*: advanced manufacturing engineering data (relations between parts/tools/processes), build sequence planning and machining data, work cell definition and plant layout, and so on

Both types of data are closely related to the geometric model provided by CAD applications. As we will see later, the quality of these CAD models will be of vital importance for a smooth integration among actors realizing the product development process.

Product Data Model

From a practical point of view, as we restrict our analysis to the available commercial technology, we propose the product data model represented in *Figure 6*. This model is built on a PDM system, which serves as the repository of the different product views that integrate the digital product master model. CAD provides the connection line among those different views.

Current technology is clearly biased towards design (Hoffmann & Arinyo, 2000). Hence, the 3-D solid models are considered as the primary view, deriving secondary views for other purposes like DMU, analysis, or manufacturing. Whichever modification of the geometry must be carried on the primary view. Now, we will analyze how the different tasks in the advanced product development process make use of the primary view:

- *Documentation*: Most of the engineering drawings are obtained from the 3-D geometric model. Projections and sections are easily created from the 3-D model. Many parametric systems propose a set of dimensions, and the user has only to select the more convenient ones. Nevertheless, in the near future, we expect the drawings to be relegated to a secondary role; and they will be even eliminated, at least in the most technologically advanced industries, as proposed in Step 3 of VDA Recommendation 4953 (Verband der Automobilindustrie, 1999), where the creation of drawings is omitted. Notice the legal implications since OEMs assign a binding nature to CAD model data (Volkswagen AG, 2002).

computer-readable form (Bloor & Owen, 1995): use of a common system, direct translation, or indirect translation by means of a neutral file. The first option is followed by many OEMs that, in order to avoid interoperability problems, impose specific software systems on their suppliers. It means imposing significant costs on suppliers, which must maintain multiple systems to satisfy the demands of multiple customers. Direct translation is another potential interoperability solution; but currently it has limited capabilities because translators are not widely available and have high maintenance costs, and proprietary formats are many times encrypted, impeding development of translators. The number of direct translators that need to be written increases exponentially with the number of systems between which one wishes to transfer information. The number of translators required to intercommunicate n systems is $n(n-1)$. The third option is to use a neutral file. Software vendors have to write two translators, one to translate his internal data form into the neutral format and the other to translate a neutral-format file into his proprietary data format. This approach has the advantage that it is only necessary to write $2n$ translators to communicate n systems, without knowing the proprietary format of other software vendors to produce viable translators. This is the more interesting alternative from an economic point of view because if we develop a rich neutral format that supports the main features found in commercial CAD systems, by only developing two translators we can communicate with all the rest of the systems.

ISO 10303 (STEP) has been chosen as the main neutral format in industry, relegating IGES and other popular formats to a secondary role. The initial release of STEP, published in 1994, provides a successful way to transfer both drawings and solid models. Nevertheless, current CAD systems provide modeling tools like parametric features, constraints, and history-based modeling not supported by the current release of STEP. Consequently, it can be said that the current edition of STEP provides a way of exchanging “static” information about the product. The information transmitted is simply a “snapshot” of the model because when making the translation, all the parameterization, constraints, and feature information is lost. This is a serious handicap for true collaborative engineering because the engineer encodes his “design intent” in the selection of features, constraints, and parameters he makes.

The proper nature of ISO standards development, based on a succession of stages (see *Table 1*), leads to a technologic gap between current CAD systems and STEP capabilities.

However, there are several initiatives directed to shorten this gap. The first one is aimed to provide “static” feature support. In 2001 two application protocols (APs) supporting features representation reached IS status. They were:

Finally the importance of the associativity concept must be highlighted; it allows changes made on the primary view to be automatically transferred to the secondary ones, avoiding many mistakes caused by the continuous variations suffered by the product model during the development process. The quest for associativity is one of the reasons that justify the adoption by big OEMs of a unique, integrated CAD system.

The Interoperability Problem

The diversity of partners and software tools, in the context of the extended enterprise, that manipulates the product digital model leads to a complex flow of product data. Usually, each system has its own proprietary data representation. As a result, product data are created and stored in multiple, incompatible formats. These incompatibilities cause imperfect interoperability among the software tools involved in the product development process. Imperfect data exchange imposes costs on the industry due to higher costs of design and production and slower completion of design changes. A study done by Gallaher, O'Conner, and Phelps (2002) concluded that poor data quality adds 10% to the cost and up to 25% to delivery time in the US tooling industry. A survey performed for the NIST Strategic Planning and Economic Assessment Office by Brunnermeier and Martin (1999) estimates the economic cost of bad interoperability in the US automotive industry at \$1 billion per year. A similar study in the German automotive industry (Trippner & Endres, 1998) calculates at approximately a half billion dollars per year the economic impact of the data exchange problem. As noted by Gallaher et al. we can distinguish three types of interoperability costs:

- avoidance costs to prevent technical interoperability problems before they occur, for example, maintaining several CAx systems in order to avoid translation issues among different systems
- mitigating costs to address interoperability problems after they have occurred, usually the cost of repairing damaged CAD models after translation, or full reworking if data exchange is unavailable
- delay costs derived from interoperability problems that delay the introduction of a new product

A correct product data exchange strategy is intimately related to later interoperability costs. There are three alternatives to transfer product data in

Table 1. Stages in ISO Standards Development

No.	Stage	Deliverable
0	Preliminary	PWI. Preliminary Work Item
1	Proposal	NWI. New Work Item
2	Preparatory	WD. Working Draft
3	Committee	CD. Committee Draft
4	Enquiry	DIS. Draft International Standard
5	Approval	FDIS. Final Draft International Std.
6	Publication	IS. International Standard

- *AP 214*: core data for automotive mechanical design processes
- *AP 224*: mechanical product definition for process planning using machining features

From a design point of view, AP 214 provides two conformance classes supporting feature-based design:

- *CC14*: conformance class for feature-based design
- *CC15*: conformance class for feature-based design with flexible feature placement

However, at this moment commercial CAD systems do not support these conformance classes yet. Work for supporting parametric- and constraint-based models in STEP began in 1995 with a new work item (NWI) for ISO 14959: parametrics data exchange. However, in 1997 the development of ISO 14959 was cancelled, and related developments were transferred to ISO 10303. Then, in 1998 two initiatives were launched to accomplish the development of parametrics inside STEP: a preliminary work item (PWI) titled “History-based shape modeling” and a NWI titled “Parametrization and constraints for explicit geometric product models.” In 2000, a second NWI with the title “STEP assembly model for products” was set up for supporting 3-D parametric assembly of parts.

currently only 17% (\$156 million) of the potential benefits of STEP are being carried out. The completion of these new STEP parts will increase savings significantly, providing support to many advanced features found in commercial CAD systems.

Product Data Quality

The growing importance of product data exchange for the product development process in the context of the extended enterprise has been analyzed in previous sections. However, we must distinguish between *intrinsic* and *extrinsic* problems related to the data exchange process. Intrinsic problems are those related to the structure of the CAD model before any translation process begins, while extrinsic problems are related to those issues appearing during translation. We have concluded that the development of STEP is the best solution to solve the extrinsic problems (Vergeest & Horváth, 2001) that appear during the data exchange process. At this point, we are going to focus on the intrinsic aspect of the product data exchange problem. It is here that the concept of product data quality is fundamental in understanding the origin of many problems that suppose impediments to collaborative engineering.

Data Quality Definitions

The Automotive Industry Action Group (AIAG) defines product data quality in the following way:

“Quality Product Model Data is constructed accurately, completely representing the geometric model (math data), and accurately and completely representing all additional information in a way that can be shared and used by multiple users and managed with a minimum effort.”

However, Phelps (1999) proposes a more simple definition:

“Product data quality is a measure of the accuracy and appropriateness of product data combined with the timeliness with which those data are provided to all the people who need it.”

This definition is close to the concept of data quality coming from the software engineering domain, where a list of desirable quality dimensions is defined. For

In the medium term STEP is expected to implement 2-D parametric sections (explicit geometry supporting different types of geometric, numeric, and algebraic constraints), 3-D parametric assemblies (connecting associations among the components constituting an assembled product and their relations), and history-based modeling. This is possible because it is relatively easy to implement with the current structure of STEP. For that, new integrated generic resources (IGR) are being implemented:

- 2nd edition of Part 42: Geometric and topological representation. Status: IS.
- Part 50, Mathematical constructs: This part of ISO 10303 specifies the resource constructs for the explicit representation of mathematical structures and data related to properties of a product. Status: IS.
- Part 51, Mathematical description: Specifies the use of mathematical values for identification of properties, products, states, or activities; the use of mathematical spaces as identification schemes for spaces or sets of properties, products, states, or activities; and the use of mathematical functions to describe property variation within a set or space of products, states, or activities. Status: DIS.
- Part 55, Procedural and hybrid representation: Defines fundamental resources for the representation of models by the sequences of operations used to construct them.

In addition to these IGRs there are two integrated application resources (IAR):

- Part 108, Parameterization and constraints for explicit geometric product models: Provides general representations for parameterized quantities and for constraint relationships between entity data type instances in models. Transfer of this information with product shape models of Brep and related types captures key aspects of design intent that govern the behavior of a transmitted model in a receiving system. Status: DIS.
- Part 109, Component relationship and assembly constraints for assembly model of a product: Specifies the resource constructs for the representation of the detailed geometric relation between constituents of an assembly model, including geometric constraints between them. Status: CD.

Gallaher et al. (2002) estimate that current release of STEP has the potential of save \$928 million (2001\$) per year by reducing interoperability problems in the automotive, aerospace, and shipbuilding industries. This study shows that

example, Ballou and Pazer (1985) identify four dimensions of data quality: accuracy, completeness, consistency, and timeliness.

Other approaches give a wider vision integrating contextual aspects of data quality. Thus, Shanks and Corbitt (1999) propose a semiotic data quality framework based on four levels: the syntactic (structure of data), the semantic (meaning of data), the pragmatic (usage of data), and the social level that concerns the shared understanding of the meaning of symbols.

Another important idea noted by Wand and Wang (1996) is that the notion of data quality depends on the actual use of data. They agree with many other authors who define data quality as “fitness for use,” showing that the concept of data quality is relative. Finally, they also note that as important as defining the concept of data quality is, it is also important to know how it is to be measured.

Product Data Quality Standards

Nowadays, the most extended product data quality standard is VDA 4955 (Verband der Automobilindustrie, 2002) and its equivalent ODG11CQ9504 “ODETTE CAD/CAM Quality Assurance Method” ODETTE standard. Although originated in the automotive sector, it has been adopted in many other industries. VDA 4955 provides quality criteria for both geometrical and organizational aspects of CAD/CAM data. These criteria can be implemented in software applications known as quality checkers to automate quality auditing.

The geometric criteria (see *Table 2* for an example) analyze the polynomial degree of curves and surfaces to avoid undesired oscillating curves and rippling surfaces. There are criteria for checking the orientation and parametrization of curve elements and surfaces. The detection of surface and curve defects (overlaps, steps, and gaps) and the analysis of their continuity are very important for downstream applications such as NC processing and coordinate measuring machines (CMM). The organizational criteria of VDA 4955 propose some recommendations related to model naming and structuring, drawing generation, and modeling methodology.

Other organizations in the automotive industry have developed similar standards. Thus, the French association GALIA has developed the standard CAO.3 y CAO.4 with similar content to VDA 4955. The Japan Automotive Manufacturers Association (JAMA) has recently developed a standard related to product data quality. In the US, the Automotive Industry Action Group has established its Vehicle Product Data Quality (VPDQ) workgroup after the organization identified product data quality as the highest priority issue affecting product development in supply chains.

With the objective of unifying the emergent national recommendations related to product data quality, the “Strategic Automotive Product Data Standards Industry Group” (SASIG), established in 1995, is working on developing an international recommendation (SASIG-PDQ) for product data quality in the automotive industry. This group is integrated by AIAG, VDA, GALIA, JAMA, ODETTE Sweden, Australia’s Federal Chamber of Automotive Industries (FCAI), and the Japan Automobile Parts Industry (JAPI). The first version of this recommendation was released in 2001 (Automotive Industry Action Group, 2001).

Implementing a Product Data Quality Strategy

Product data quality (PDQ) can be analyzed from three points of view. Thus, three levels of quality can be distinguished (Contero, Company, Vila, & Aleixos, 2002):

1. *Morphological*: related to the geometrical and topological correctness of CAD models
2. *Syntactic*: evaluates the use of the proper modeling conventions
3. *Semantic/pragmatic*: related to CAD model capability for reusing and modification

Improving quality at these three levels is an important aid to supporting collaborative engineering. It is important to adhere to some PQD standard, such as VDA 4955, that provides a good reference for analyzing morphological quality. Syntactic quality can be improved by circulating the proper configuration files and start parts, assemblies, and drawings among the members of design teams. Also, modeling conventions (for example, naming conventions, layer structure, and part/assembly parameters and attributes) are a basic issue to avoid data-sharing problems and provide an easier understanding of CAD models. Semantic quality is related to the structure of the CAD model. Complex parts with more than 100 features become difficult to modify because of the multiple interrelations among features. Modeling methodology is a key issue in this context so it is very important to document the “best practices” for building complex CAD models and make this information available through “modeling guidelines” to design teams.

Commercial quality checkers provide a valuable help to enforcing morphological and syntactical checks. The more widespread checkers are:

- Parametric Technology: ModelCHECK
- Transcend Data: CAD/IQ

Table 2. Geometric Data Criteria in SASIG-PDQ 1.0

Quality code & Category		Entity Category							Model G-MO
		Curve G-CU	Surface G-SU	Edge G-ED	Edge Loop G-LO	Face G-FA	Shell G-SH	Solid G-SO	
LG	G ₀ Discontinuity	Large segment gap	Large patch gap		Large edge gap		Large face gap		
NT	G ₁ Discontinuity	Non-tangent segments	Non-tangent patches				Non-tangent faces		
NS	G ₂ Discontinuity	Non-smooth segments	Non-smooth patches				Non-smooth faces		
EG	Edge Gap					Large edge face gap			
VG	Vertex Gap					Large vert. gap			
CR	Curvature-Radius	Small curve radius of curvature	Small surface radius of curvature						
WV	Wavy	Wavy planar curve	Wavy surface						
FO	Folded		Folded surface						
DC	Degenerate Curve		Degenerate surface boundary						
DP	Degenerate at Point		Degenerate surface corner						
SA	Sharp Angle				Sharp edge Angle		Sharp face Angle		
TI	Tiny	Tiny curve or segment	Tiny surface or patch	Tiny edge		Tiny face		Tiny solid	
NA	Narrow		Narrow surface or patch			Narrow face			
RN	Relatively Narrow		Relatively narrow neighboring patches			Narrow region			
IS	Intersection	Self-intersecting curve	Self-intersecting surface		Self-intersecting loop	Intersecting loops	Self-intersecting shell	Intersecting shells	
NN	Non-NURBS			Non-NURBS edge		Non-NURBS face			
IK	Indistinct Knots	Indistinct curve knots	Indistinct surface knots						
HD	High-Degree	High-degree curve	High-degree surface						
FG	Fragmented	Fragmented curve	Fragmented surface	Fragmented edge					
CL	Closed			Closed edge		Closed face			
IT	Inconsistent Topology			Inconsistent edge on curve	Inconsistent edge in loop	Inconsistent face on surface	Inconsistent face in shell		
FR	Free						Free edge		
NM	Non-Manifold						Over-used edge		
OU	Over-Used						Over-used vertex		
MU	Multiple					Multi-region face		Multi-volume solid	Multi-solid model
EM	Embedded	Embedded curves	Embedded surfaces			Embedded faces		Embedded solids	
UN	Unused		Unused patches						
VO	Void							Solid void	
NU	Non-Updateable							Non-updateable solid	
MH	Missing History							Missing solid construction history	
UH	Unused History							Unused solid construction history	
HY	Hybrid								Hybrid model

- Prescient Technologies: DesignQA
- Software Factory: PE Check
- TransCAT: Q-check

Most of the quality checker applications are based on Web browser technology, where recommendations are presented to the user in the form of an HTML, XML and Java-based report, which appears in the user's Web browser. A

quality evaluation process must be done before exchanging models with other CAD systems or submitting them to a PDM server. Commercial tools support both interactive and batch processes to automate the checking process.

Conclusions

Collaborative engineering represents the natural evolution of the concurrent engineering approach to product development. The expansion of new enterprise architectures as the extended and virtual models is possible due to the advances of communication tools that break the geographic barriers and the impressive capabilities of computer-aided tools. However, both communication and computer-aided tools heavily depend on the digital product representation. Currently, problems related to the interchange of these digital models are one of the most important obstacles to success in implementing collaborative engineering.

We have distinguished *intrinsic problems* to data exchange as those related to the structure of the CAD model before any translation process begins and *extrinsic problems* as related to those issues appearing during translation. We have concluded that the development of STEP is the best solution to solve the extrinsic problems, extending its current capabilities to support 2-D parametric sections, 3-D parametric assemblies, and history-based modeling.

Product data quality is a key issue to avoid intrinsic data exchange problems and simplify the integration of downstream applications in the design chain. Development of commercial quality checkers and product data quality standards, such as VDA 4955 and SASIG-PDQ 1.0, shows the growing interest and importance of this topic.

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Chapter V

Collaborative Decision Making

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Abstract

This chapter introduces the collaborative decision making (CDM) framework as a means of employing a systematic approach to develop collaborative systems in an electronic business environment. It argues that the CDM framework provides a holistic view of the components that play critical roles for collaboration, which include group facilitation and coordination, knowledge repositories, dialectic decision support, and discussion strategy support. The framework emphasizes the importance of supporting dynamic collaboration across multiple aspects of the group decision making process as a basic requirement. This chapter identifies the major components of decision support functionalities that need to be embedded in CDM systems so as to reduce the cognitive burden of decision makers.

Introduction

Corporate business practices and strategic applications are becoming increasingly globalized through expansions, diversification, and joint ventures. Advanced telecommunications and computer network technologies have enabled the emergence of a new organizational model such as a virtual team or a virtual enterprise. In virtual enterprises and in the strategic, tactical, and operational communities, decision makers have distinct complimentary areas of expertise and are geographically and often temporarily distributed over the globe (Lipnack & Stamps, 1997; Raghu, Ramesh, Chang, & Whinston, 2001; Raghu, Ramesh, & Whinston, 2003; Ramesh & Whinston, 1994; Townsend, DeMarie, & Hendrickson, 1998). Most of the decisions have become increasingly complex, as the level of professional and technical skills required is becoming very sophisticated, reaching into deeper levels of specialization in narrower domains. A hypercompetitive business environment further emphasizes the need to collaborate and bring together geographically dispersed individuals and rally their contributions. These trends together emphasize the need for effective and efficient teamwork among distributed group members (Dennis, 1996; Panko, 1991). Group work includes problem solving, decision making, resource allocation and coordination, and task structuring. Since groups tend to have a broader range of skills and abilities than individuals, groups often can deal with complex tasks more effectively than individuals (Finnegan & O'Mahony, 1996). However, group decision making requires collaboration and continuous interaction of various parties involved in order to maximize the effectiveness of group decision making.

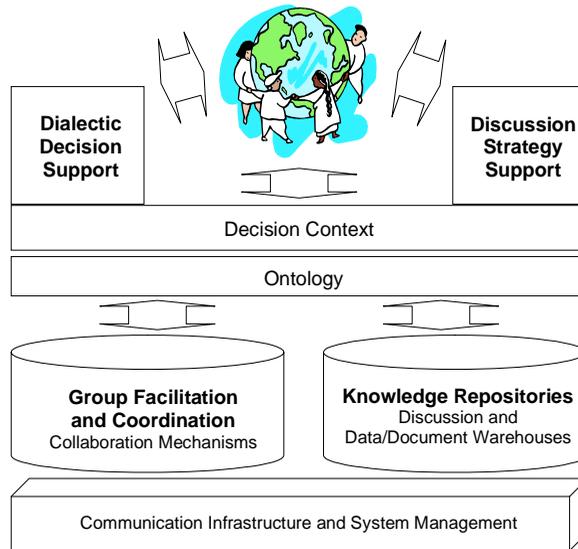
The key to achieving effectiveness in collaborative work lies in effective communication among group members. Collaborative decision making by a group of distributed individuals typically involves an informal structure where group members debate various decision alternatives, which requires effective conflict management and coordination. To arrive at an acceptable resolution, collaborative decision making occurs via the exchange of ideas, information, and data to enable an understanding of mutual positions on the decision issues. Over the last decade, many advances have been made in information technology to support collaborative work when faced with distance and time barriers. Ranging from teleconferencing and messaging systems (Nunamaker, Dennis, Valacich, Vogel, & George, 1991) and electronic meeting systems (Barua, Chellappa, & Whinston, 1995) to intelligent agents (Sheth & Maes, 1993) and workflow systems, computer-supported collaborative work (CSCW) has focused on studies of tools and techniques that enable effective distance communication in collaborative work processes, as well as their psychological, social, and organizational effects. Collaborative computing technologies such as group support

systems (GSSs) have enabled group interactions among dispersed members within an organization (Jarvenpaa, Rao, & Huber, 1988; Vogel, Nunamaker, Martz, Grohowski, & McGoff, 1990). GSSs have enabled people with different backgrounds to communicate and coordinate group interactions to generate and organize ideas, evaluate proposed alternatives, and make decisions (Dickson, Poole, & DeSanctis, 1992). Coping with distance and time barriers, group members can display documents online and discuss the contents via e-mail asynchronously or via electronic meeting rooms synchronously. In addition to streamlining collaborative work by enhancing knowledge acquisition and sharing among group members, researchers and practitioners in the CSCW field have attempted to improve the quality of decisions made through the use of computer-based information systems. Recent advances combine group discussion software with more advanced features to support both structured and unstructured electronic communication for collaborative work such as brainstorming, information gathering and sharing, consensus building, and decision making (Zwass, 1998). Effects of these collaborative systems have reached other domains as well. For example, information retrieval (IR) systems incorporate collaborative filtering techniques to enable decision makers to retrieve wanted documents based on document contents and annotations made by other users (Romano, Roussinov, Nunamaker, & Chen, 1999).

This chapter draws from and reviews the foundational concepts of collaborative decision making and decision support from broad streams of research, including CSCW, GSSs, and artificial intelligence. While the literature in each of these streams is extensive, we will focus on some of the immediately relevant and important works in these domains. The aspect of *social awareness* is important to collaborative work. An awareness of social group issues can be achieved through the understanding of the behavior and actions of groups, and collaborative computing technologies can aid in the social conditions of work groups (Anderson, 1991; Valacich, George, & Nunamaker, 1994). Collaborative decision making within a social setting is achieved within groups of decentralized members that cooperate to achieve objectives that are typically beyond the capabilities of any individual member. As such, collaborative decision making can be viewed and modeled as a type of distributed reasoning process, whereby a group collaboratively engages in a search and negotiation process to reach an agreement or a solution. While a number of theoretical models have been proposed for investigating decision making in a social setting, little research has covered the full breadth of social and cognitive activities that are typically involved in a collaborative decision-making process.

We present an integrative framework for collaborative decision making (CDM) to facilitate an effective design of a system that is rooted in the pragmatics of organizational decision making and that avoids many of the problems with the conventional decision-analysis tools (*Figure 1*). CDM can also serve as the

Figure 1. Collaborative Decision-Making (CDM) Framework



basis for providing support for argumentative processes through a common knowledge base for collaborative decision making. We address the CDM framework from four broad perspectives: group facilitation and coordination, knowledge repositories, dialectic decision support, and discussion strategy support. Each of these perspectives shares some requirements on basic system components as backbone services. This framework highlights what features to expect in future collaborative decision-support systems and how such features can enhance productivity in groups and distributed decision-making processes. Providing system support for enabling distributed teams to coordinate has been studied extensively in the literature. First, under *group facilitation and coordination*, we will discuss the recent trends in the areas of CSCW and collaborative technologies such as GSSs. The focus here will be both on the technology and social aspects. Second, to establish *knowledge repositories*, organizations require a unifying, semantically developed structure to represent knowledge and share information. The volumes of data and diversity of expertise, culture, language, and vocabularies exacerbate the complexity of knowledge storage and retrieval. CSCW literature has indicated that to make teamwork effective, decision makers need to work collaboratively based on a shared information base (Dennis, 1996; Gray, Mandviwalla, Olfman, & Stazinger, 1993). To facilitate communication among such heterogeneous teams, it is imperative for organizations to develop unified knowledge and data repositories. In this context, using the knowledge management perspective, we will discuss the importance of building domain ontology and taxonomies that will play a key role in shaping collaborative decision-support systems of the future. Finally,

dialectic decision support and *discussion strategy support* are two aspects of collaborative decision making that are perhaps the least understood. Considerable research in the areas of argumentation analysis, natural language processing, and structured knowledge interchange has taken place over the past few years. It is critical to recognize group development as a social process and accommodate collaborative techniques such as negotiation when designing system support for collaborative decision making. However, application of these fundamental areas in collaborative decision making has been scarce if not nonexistent. We will devote a considerable portion of this book chapter in presenting our views on what roles dialectic decision support and discussion strategy support play in supporting collaborative decision making.

Group Facilitation and Coordination

CSCW has been defined as:

“An endeavor to understand the nature and requirements of cooperative work with the objective of designing computer-based technologies for cooperative work arrangements” (Schmidt & Bannon, 1992, p. 11).

Research in CSCW requires a multidisciplinary approach to study how people collaborate using communication and computer technology. Research topics include not only the design and use of collaborative technologies, such as electronic mail, videoconferencing, group authoring, and group decision support, but also sociological and psychological aspects associated with the use of those technologies. Decision problems that groups deal with often require the knowledge of a group of people with diverse backgrounds. For instance, during brainstorming sessions, participants generate and post their ideas synchronously and vote on the ideas generated using the system in real time. By removing distance barriers, providing techniques for structuring decision analysis, and systematically directing pattern, timing, or content of the discussion, more ideas can be presented and analyzed than in a traditional face-to-face meeting (DeSanctis & Gallupe, 1987). Thus, collaborative systems can support and organize human parallel processing, allow broader input, and promote more representative participation and discussion than in a typical face-to-face environment (Zwass, 1998).

Research on group work and collaborative systems in the information systems area has focused extensively on a particular class of computer-based systems

called groupware. Group decision support systems (Huber, 1982), a kind of groupware, are computer-based systems that facilitate group communication with the purpose of improving the decision-making process (Bui & Jarke, 1986; DeSanctis & Gallupe, 1987; Hiltz, Turoff, & Johnson, 1989). GSSs, grown from GDSSs, have been defined as a blend of human intelligence, information technology, and software that interact to solve complex problems (DeSanctis & Gallupe, 1985; Huber, 1980; Romano et al., 1999). Specifically, GSSs are defined as computer-based information systems to support intellectual collaborative work that consist of networked computers, software, and typically a public screen (Ellis, Gibbs, & Rein, 1991; Jessup & Valacich, 1992; Romano et al., 1999). GSSs support group decision making by providing group members with common space and helping a team of decision makers to perform group decision-making tasks through the interactive sharing of information (DeSanctis & Gallupe, 1987; Huber, 1984). The literature indicates that there have been many types of GSSs to meet the diverse business needs, including strategic group decision support systems (SGDSSs; Finlay & Marples, 1992), group communication support systems (GCSS; Pinsonneault & Kraemer, 1990), and distributed group decision support systems (DGDSS; Jacob & Pirkul, 1992). There are many kinds of commercially available GSSs, for example, Beauclair and Straub (1990) found that some 78 different GDSSs were being used by the companies in their sample. Some representative GSS packages are summarized in *Table 1*.

Methodology for the design and development of collaborative systems has to address both technology and social aspects. Research in this area, therefore, is concerned with diverse issues, ranging from systems development aspects of groupware technologies to sociological issues at work (Bannon & Schmidt, 1991). Advances in computing and communication technology, multiuser interface, and concurrency control have helped collaborative systems to gain wider acceptance and to demonstrate benefits for group activities (Romano, Nunamaker, & Briggs, 1997). For example, *Recommender* systems provide integrated support for collaborative searching and visualization of results, which helps decision makers search for and quickly retrieve relevant and meaningful information through automated situation analysis and course-of-action generation and recommendation (Nunamaker, 1997; Romano et al., 1999). *Recommender* systems seek to decrease the problem of information overload, using a technique called *collaborative filtering*, which was originally used to provide an effective and efficient way for users to search through large volumes of information. According to Maltz and Ehrlich (1995), the concept of collaborative filtering originated with the Information Tapestry project at Xerox PARC. Collaborative filtering is based on the premise that many people have common interests and, therefore, can provide each other with valuable recommendations (Goldberg, Oki, Nichols, & Terry, 1992; Maltz & Ehrlich, 1995). Collaborative technologies have also fast evolved toward open, Web-based environments and are increas-

Table 1. Status of Group Support Systems Environment

<i>System</i>	<i>Technique</i>	<i>References</i>
DTC Lab	Brainstorming, voting, ranking	
MCC system	Electronic black board	Jarvenpaa et al. (1988)
PlexSys	Whole array of toolbox, including brainstorming, voting, ranking specialized questionnaire, policy formation, etc.	George (1989)
GroupSystems	Brainstorming, voting, ranking specialized questionnaire, policy formation, anonymity, evaluation, issue analyzer, session director, stakeholder identification and assumption surfacing (SIAS), alternative evaluator, issue prioritization, group dictionary, group writer, group outliner, topic commenter, idea generator, categorizer, group matrix, survey, text editor, clipboard, calendar, etc.	Dennis et al. (1990)
SAMM	Brainstorming, voting, ranking specialized questionnaire, policy formation, etc.	DeSanctis et al. (1987)
SAGE (Software Aided Group Environment)	A Macintosh based derivative of SAMM	Raman et al. (1992)
Meetingware	Similar to GroupSystems and SAMM	Lewis (1992)

ingly used in a number of other contexts. The existence of an open environment becomes increasingly important to support dynamic collaboration and ensure the effectiveness and efficiency of collaborative systems for ever-expanding organizational boundaries. For instance, workflow management systems are increasingly shifting organizational paradigms by providing new operational means for organizational activities.

It is well acknowledged that while a group problem-solving method may be similar to an individual problem-solving method, group problem solving is more complex than individual problem solving (Finnegan & O'Mahony, 1996; Hohmann, 1997; Simon, 1997; Wong, 1994; Zhang, 1998). Hohmann emphasized the importance of communication and collaboration in a group problem-solving process, arguing that cognitive activities that occur in a group are even more varied than those in individuals on account of the interplay of cognitive activities among individuals. His collaborative model identifies several group-oriented processes such as distributing tasks to individuals, coordinating team outcomes, and integrating solutions. Simon presents a collaborative decision-making model, stressing the need for group-level understanding of the problem, arguing that group-level objectives facilitate coordination in a group. Wong specifically focuses on conflict resolution, including negotiation attributes as part of the

collaborative decision-making model, yet lacking the coordination of activities between group members. The challenge for collaborative systems is therefore to focus on facilitating group interaction, with an emphasis on communication, collaboration, and coordination in a group. The supporting/contradicting evidential data presented in a collaborative decision-making process can grow significantly in both size and complexity, producing information overload and causing a substantial cognitive load on the decision makers and the group. The literature in CSCW has demonstrated that computer-generated feedback is an effective decision aid for dealing with cognitive conflict tasks during collective activities (DeSanctis & Gallupe, 1987; Hogarth, 1987; Sengupta & Te'eni, 1993). Ramesh and Whinston (1994) proposed the architecture called *argumentative reasoning facilitation systems* (ARFSs) to provide this support by structuring and facilitating discussions throughout. The expected end results include a reduction in the cognitive load on the decision makers, a better understanding of the issues, and possibly faster convergence to fairly well-supported decisions. Along the same line, it is argued that due to the dynamic and complex nature of tasks and the voluminous information dealt with, groups may need a knowledge management process and an integrated environment to support that process (Romano et al., 1997).

Collaborative systems research also deals with diverse behavioral and sociological aspects, including culture, group dynamics, and political aspects such as power and influence. It is noted that most applications have emphasized technological aspects rather than sociological aspects (Alter, 1992). Fulk, Schmitz, and Steinfield (1990) argue that behavior and sense-making are subject to social influence. Therefore, investigating social processes is a necessary step towards an understanding of group behavior. Such understanding is crucial when attempting to support group processes via collaborative systems. There is evidence to the effect that social factors often influence the nature of the work process and the ways in which the technology is used (Giddens, 1984; Orlikowski & Baroudi, 1991). Forsyth (1990) argues that group members influence one another through social interaction. A large body of literature has investigated dysfunctional properties of group decision making. Various social processes in groups are considered detrimental to the quality of decisions and the performance of groups. For example, it is argued that groups may be prone to *groupthink*, a drive for consensus that overrides realistic appraisal of decision alternatives (Esser, 1998; Janis, 1982). The source of *groupthink* is a group's cohesion, which may lead to a lack of productive criticism and subsequently inferior quality of decision. Groups often have norms that perform an important regulatory function in small groups (Baron, Kerr, & Miller, 1992). Defined locally as a standard or rule that is accepted by group members, group norms may have substantial impact in eliciting conformity to specific solutions.

Social influence is often divided into two perspectives: normative and informational influence. Normative influence refers to the conformity that results from a person's desire to gain acceptance (Deutsch & Girard, 1955). This occurs to enhance one's position in the group and to maximize social rewards such as acceptance and status (Sanders & Baron, 1977). Normative influence results from the belief that others' views are socially desirable. This occurs when an individual's actions are open to actual or anticipated surveillance from the group or fear of rejection or punishment. Informational influence, or persuasive arguments, refers to the conformity that results in a situation from accepting evidence about reality provided by others. It derives from the belief that others' views are valid and reliable (Deutsch & Girard; El-Shinnawy & Vinze, 1998). This occurs when one tries to persuade others through valid arguments with the use of logic or verifiable facts (Bishop & Myers, 1974). This type of influence is greatest when one is unsure of one's own ability to make an accurate judgment in a particular situation (possibly from the lack of adequate evidence). Researchers and practitioners have recently paid serious attention to the organizational and sociological issues such as work structure to better deal with difficulties of decision-making processes in a group (Gopal & Prasad, 2000).

Knowledge Repositories

The absence of logical mental structuring in collaborative decision making could lead to a poor grasp of the issues by decision makers. Decision making is almost always domain dependent and so is reasoning. It is well acknowledged that the volumes of data and diversity of culture, language, and vocabularies collectively impose a significant burden on decision makers to perform decision-making tasks. As such, sharing the same mental structure is very critical for decision makers to be productive. To facilitate communication among culturally and/or technically diverse populations of people and systems, it is therefore imperative to impose uniform semantic structures where possible and define contextual metadata on other sources of information to enable dissemination of information across different levels of organizations (Raghu et al., 2003). CDM environments need to support meta-information on which group members can rely for effective information exchange in a session (Gray et al., 1993). CDM systems, therefore, should provide tools that model the world for any given domain and support a unifying, semantically developed structure, such as the domain knowledge ontology of an underlying project. For example, in the domain of software engineering, languages for requirement, design, and implementation should be well established beforehand to ensure the effective use of collaborative systems.

Standardization at the semantic level, in this vein, plays a critical role by developing standard ontology for a specific domain.

The development of domain-oriented ontology may be required to alleviate difficulties described above. Ontology is “*the basic structure or armature around which a knowledge base can be built*” (Swartout & Tate, 1999), which characterizes mechanism and content of domain conceptualization, free of technical requirements (Chandrasekaran, Josephson, & Benjamins, 1999; Edgington, Choi, Henson, Raghu, & Vinze, in press; Kim & Fox, 2002; O’Leary, 1998; Swartout & Tate, 1999). In the context of knowledge management systems, ontology is a taxonomy of relationships that defines the knowledge, along with a conceptual model, a thesaurus, and a set of expanded attributes. The conceptual model represents the metadata encompassing the set of relationships among concepts, which can be formed from shared vocabulary. A thesaurus complements the model by documenting the various names and labels attached to the things in the model (Edgington et al., in press). In the artificial intelligence domain, a knowledge base is a computer-readable translation of an ontology. It is widely recognized that constructing ontologies is an important step in the development of knowledge bases. Ontology, once incorporated in collaborative systems, can serve as a link between decision makers and information. It logically abstracts the information so as to provide the concepts and relations and retrieve relevant information based on inference functions, which could fulfill “information retrieval.” The techniques and industry standards that facilitate the development and implementation of ontologies are briefly summarized in *Table 2*.

Unlike data-centric information systems that cannot incorporate context into reasoning processes, information-centric systems can understand the information being processed through structured information representations. The ontology-enabled knowledge base may be dynamic or static. It is increasingly critical for large-scale ontology-based systems to allow for dynamic ontology definitions instead of static, predefined standards. That is, we need to allow client agents to discover the ontology of services at runtime, enabling opportunistic access to remote information. As clients incorporate new ontology into their own internal information models, the clients build context that enables them to reason on the information they receive from other systems. For example, a multi-agent architecture for CDM can consist of ontology services and domain servers that integrate data obtained from diverse heterogeneous sources to provide information repository services. The use of ontology can provide a context that enhances the ability of intelligent agents with their own knowledge and information base to reason about information received. Once formulated, the system can mature as new knowledge is captured by the system and entrenched in the knowledge base (Pohl, 2001).

Table 2. *Ontology-related Technology*

Category	Description
Industry Standards	<ul style="list-style-type: none"> • ISLE (International Standards for Language Engineering): Publicly available language resources. • TopicMaps (ISO/IEC 13250 standard) to capture semantics by providing a terminology and link to resources. • DAML-O (DARPA Agent Markup Language Ontology Language): A language for the core ontology of the language. • OIL (Ontology Interchange Language): OIL is the first ontology representation language that is properly grounded in W3C standards such as RDF/RDF-Schema and XML/XML-Schema. • RSS (RDF Site Summary): An XML application, conforming to the W3C's RDF Specification. • SUO (IEEE Standard Upper Ontology): A specification of the semantics of a general-purpose upper level ontology.
Ontology Codification Languages	GFP (Genetic Frame Protocol), OKBC (Open Knowledge Base Connectivity), KIF (Knowledge Interchange Format), CycL (Cyc representation Language), etc.
Ontology Tools	Protégé-2000, Ontology Builder, Apollo, OIEd, LinkFactory, OntoEdit, JavaSkyLine, Documentum, OntoWeb, Ontolingua Server, OntoSaurus, OpenKnoME, SymOntoX, WebODE, WebOnto, etc.

In CDM, ontology can be used as a specification medium for describing a domain that can be used as the foundation for a knowledge base around which group facilitation and coordination can be structured. For decision makers, ontology can provide a structured vocabulary for interaction between systems and people. The goal is to communicate consistently in a domain of discourse without necessarily operating on a globally shared theory. Thus, the main challenge is the volume and number of different information sources that would potentially feed useful and usable information to CDM systems.

Dialectic Decision Support

In a real-world situation where the group determines courses of action collectively and argumentatively, it is not the case that all the decision alternatives are available up front, but instead they evolve from analyses and argumentation during collaborative decision making. The consensually reached determinations of possible outcomes capture the imagination, involvement, and collective conviction of group members in choosing action plans. The traditional tools are *prescriptive* models of decision making. To facilitate the decision makers in arriving at a best consensual decision, a *descriptive* model of argumentation

process provides the basis for structuring, coordinating, and integrating group interactions in a practical and efficient manner (Ramesh & Whinston, 1994). Logical structuring of arguments and coordination are crucial to effective group decision making.

Frameworks for early single-user decision support systems are based on classical decision theory. These frameworks have been widely used to identify a range of decision options and possible scenarios, to estimate potential outcomes for each scenario, and then to assign quantitative probabilities to these scenarios and utilities to the outcomes (Von Neumann & Morgenstern, 1944). Some of the exemplary approaches include game theory, decision analysis, multi-criteria decision making, and generalized approach for structuring and modeling negotiations (Kersten & Szapiro, 1986). When decision makers act rationally to choose a course of action, game theory can be instrumental in the analysis of situations where there is a conflict of interest. The assumptions of perfect rationality and perfect or near perfect knowledge of all parties lead to a prescriptive orientation. Game theory is a very rigorous approach to conflict resolution that provides a formal problem analysis.

Decision analysis tools based on classical decision theory have encountered numerous problems. First, they require a prior knowledge of all decision alternatives and possible outcomes, while decision alternatives actually evolve and the outcomes could change over time in many organizational decision processes. Consequently, they fail to capture fully the time-dependent development of decisions in organizations (Ramesh & Whinston, 1994). Second, they rely heavily on quantitative parameters, such as outcome probabilities, whose interpretation is not always objective. This is consistent with a well-established finding from psychological research that human decision makers do not manage uncertainty in ways that closely resemble classical normative probabilistic reasoning (Kahneman, Slovic, & Tversky, 1982; Nisbet & Ross, 1980; Parsons & Fox, 1996). Decision tools employing a quantification of subjective assessments may fail to capture the imagination or conviction of the decision makers that may arise when they are justified argumentatively. Even in the intuitive cases, at least partially supporting lines of reasoning are usually presented to win group support (Ramesh & Whinston, 1994). Third, they usually employ decision criteria, such as expected payoffs and others, which may not necessarily be robust against deviations (Huber, 1981) and be truly consistent with group behavior in the real world. Finally, they ignore a key element of organizational decision making: argumentation.

The important decisions in many organizations are products of argumentation and conflicting positions. Many working relationships could be a mix of elements such as cooperation, conflict, competition, collaboration, commitment, control, coercion, and coordination (Kling, 1991, p. 85). For instance, a claim can be

defeated by new information, and a conclusion could be reached through a chain of such defeasible reasons. Argumentation is a rational, social activity aimed at defending a standpoint so that it is acceptable. Dialectic is a form of argumentation process, of which the appropriateness of formal dialectics has been studied as a basis for defeasible reasoning (Loui, 1993). The problems described above illustrate the difficulties for applying conventional decision theory to human decision making. Parsons and Fox (1996) drew on the work carried out at the Imperial Cancer Research Fund, suggesting that a knowledge-based, semiquantitative model, such as a symbolic decision model that uses argumentation as the basic framework, gives a better account of human reasoning under uncertainty than a statistical model. They also suggested that argumentation offers a complement to numerical methods for reasoning about a general framework within which many competing approaches can be understood and that group decision support systems built based on this model have a number of advantages over conventionally available technologies.

The basis for dialectical decision support in the CDM framework can come from argumentation theory. In a collaborative discussion process, the discussion takes the form of argumentation, where the positions of some individuals can be challenged. Decisions following the discussions should be made not only on the information presented during discussions but also on the strength and validity of the reasoning process that ties the discussion together (Peleman, 1979; Peleman & Olbrechts-Tyteca, 1969). Reasoning in general may be categorized into *strict* and *defeasible* reasoning (Vreeswijk, 1992). While strict reasoning is structurally coherent and logically consistent, and is thus not open to argumentation, defeasible reasoning includes structures and logic that are open to argumentation. A group will focus on a discussion's defeasible components, and systematic support is needed in this area (Raghu et al., 2001). Defeasible reasoning arises due to perceptual differences among individuals about claims that lack a strong support base in terms of evidential data or strict reasoning. The resolution of the difference hinges on strengthening the support base and/or persuasive presentation. Therefore, any analytical approach to assess a claim as "winning" or "losing" needs to model these differences and can at best be heuristic. Many researchers have attempted heuristic resolution of defeasible logic, as well as providing structural formalisms for representation (Fischer, Lemke, McCall, & Morch, 1991; Hua & Kimbrough, 1998; Lin & Shoham, 1995; Loui, 1993, 1994; Nute, 1988; Nute & Erk, 1998; Nute, Hunter, & Henderson, 1998; Pollock, 1987, 1991; Swanson, 1988; Vreeswijk, 1992).

Argument analysis for logical consistency and coherence has traditionally been considered in the domain of logic and philosophy (Kimbrough, 1986; Locks, 1985; Mitroff, Mason, & Barabba, 1982; Toulmin, 1958; Toulmin, Rieke, & Janik, 1979). In the modern theory of argumentation, Toulmin played a significant role in that he developed a structure of argument that captures the layout of

arguments. Toulmin proposed a conceptual model of argumentation to capture the dynamics of the process of reasoning in argumentation, elaborating argumentation schemata by using a pictorial expression relevant for argumentation. Focusing on practical significance of logic, Toulmin analyzed the structure of arguments using five basic constructs: claims, warrants, backing for warrants, supporting data, and rebuttals (Ramesh & Whinston, 1994). As an alternative for formal logic for argumentative discourse, Toulmin's model has influenced much of theoretical research in argumentation theory by providing concepts and insights. Kimbrough develops a graph representation of arguments and develops algorithms for determining whether a claim is logically consistent with the basic premises from which the claim is derived. The system proposed by Kimbrough is a full theorem prover for sentence logic using a graph model of arguments. In short, the works of Toulmin and Kimbrough develop formalisms for argument logic representation and methods for determining the logical consistency of arguments.

Toulmin's model is problematic when applied to complex, interactive arguments. A parallel yet alternate approach to argument analysis was proposed by Lorenzen (1965, 1984, 1987), whose work on dialogue logic attempted to capture argumentation as a dialogue between a proponent and an opponent. According to the Lorenzen model, a dialogical argument game proceeds in the form of persuasion dialogue, in which one party tries to get the other to accept a thesis or, conversely, the other tries to refute the first. The Lorenzen model requires that each derived assertion be logically consistent with the earlier assertions accepted by the deriving individual. The focus of the Lorenzen model is on the proof strategies rather than on formal representation. The Lorenzen model can be used as a general framework for a theorem prover by giving hints at the complexity of the resolution process. Barth and Krabbe (1982) extend this idea of formal dialectics to describe rules for the conduct of conflict-resolving discussion. A comparison of the Toulmin and Lorenzen systems gives us useful insights in modeling argumentation processes. The Toulmin system is a representation formalism, which can be used by a theorem prover in determining the logical consistency of arguments. In contrast, the Lorenzen model is a formalism for gaming and coordination. In summary, the Toulmin and the Lorenzen systems ideally complement each other, providing a basis for the presented framework that would be most useful in designs for collaborative technologies. Together, they provide a framework for the representation and gaming of arguments.

Ramesh and Whinston (1994) integrate the approaches of Toulmin and Lorenzen and propose formalisms for recording, organizing, and coordinating argumentative discussions in organizations. Based on the formalism derived from an abstraction of argumentation process, they first developed a language for argument representation and then developed a network architecture of the arguments termed the *claims-argument-proposals* (CAP) net, which drives the

human-computer interaction. The realization of defeasible reasoning could also be used with terminological knowledge. For instance, a defeasible logic and the inference layer can be realized on the top of ontology layer so that the nonmonotonic reasoning process can adequately interact with ontological knowledge of the domain. Two types of ontologies can be considered: argument ontologies and domain ontologies. Argument ontologies can be regarded as meta-level ontologies, including components expressed in Toulmin's framework, such as reasons, defeaters, warrant, undercutters, etc. Domain ontologies can be incorporated in knowledge bases of different argumentation systems to enable quicker development of argumentation systems and to capture a more descriptive set of domain-specific properties (Hunter, 2001).

Discussion Strategy Support

Collaborative decision making in most organizations typically evolves from either formal or informal deliberations in groups where the group members consider and debate various possible decision options. Group decision making evolves out of the interactions among the group members in that decisions build on past decisions and their consequences, also affecting the course of future decisions. The dynamics of this evolution are captured in the conceptual paradigm shown in *Figure 2*. For instance, when a group in an organization has decisions to make collaboratively, the group members first analyze a case of interest and propose certain courses of action based on their respective lines of reasoning. The discussion can start with a quick review of possible options, as the group members take positions, which could be endorsements or oppositions to the claim. The group members do not always agree on specific claims and arguments, therefore causing conflicts in the group. In such cases, the decision makers are often involved with negotiation through communication. As a result of negotiation, certain actions may be accepted, while the others may be rejected. This argumentation could generate certain new proposals as well, until the primary decision issues are resolved. Consequently, the above sequence is captured in the loop between proposals, argumentation, and revised reasoning in the paradigm. Once accepted, proposals translate to decisions to implement actions contained in them. The changing environment and the outcomes of earlier decisions give rise to new issues, and the process of analysis and argumentation continues.

When individuals make statements, several implicit ideas are usually intended. These ideas mostly take the form of implied relationships that occur beneath the labyrinth of explicit assertions and are very important to mutual understanding of

argumentation process. The interactions during this process are modeled through an *argument gaming* formalism and a *coordination* formalism. These formalisms are the central components of an *argumentative reasoning facilitation system* (ARFS). The role of such systems in group deliberation is to structure arguments in a logically sound and complete framework and facilitate the interactions effectively. The CAP-net was motivated by the Toulmin system of representation, and the formalisms for gaming and coordination were motivated by the Lorenzen system of argumentation. The developed formalisms are an adaptation of the two systems to the development of practical computer aids for group decision making. The ARFS framework develops pragmatic and efficient support tools to ease the cognitive burden of decision makers, focus the group on critical issues, and guide creative positional and argument strategy development throughout the discussion in collaborative decision making.

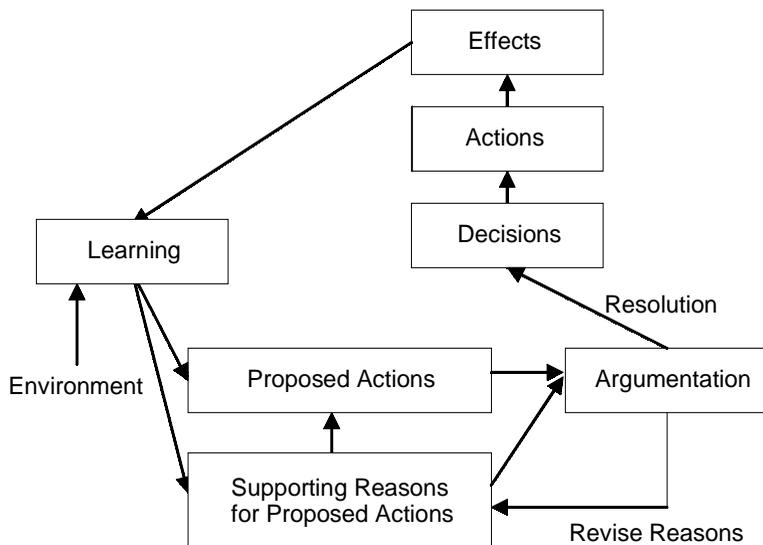
Formal models of reasoning can provide clarity and precision. Nute and Erk (1998) proposed the development of an argument-based decision support system utilizing defeasible, or nonmonotonic, reasoning. Knowledge-based systems (KBS) that model inference about specific domains incorporate representations of the knowledge necessary to solve problems in their domains, allowing users to model knowledge not already represented in the system. Such an argumentation-based system (ABS) can provide tools to help the user represent knowledge about any domain and would incorporate an inference mechanism to help the user derive conclusions from the knowledge that has been modeled. The system would make the inference process visible to the user and allow the user to construct a variety of what-if scenarios easily and quickly, eventually allowing the user to construct and evaluate competing arguments on any subject before making a decision. It incorporates a qualitative approach to the representation of uncertain or incomplete information, one that does not require the user to assign numbers to pieces of knowledge.

It is suggested that current collaborative technologies do not fully match the way organizational groups work. Van Genuchten, Vogel, and Nunamaker (1998) also suggest that the next wave in collaborative technologies development should incorporate primary work processes for wide acceptance and institutionalization. Limitations of current collaborative technologies include a simplified view of groups and an implicit prescriptive worldview in design (Mandviwalla & Olfman, 1994; Romano et al., 1999). To explicitly provide mechanisms to address social interaction in the group context, dialectical argumentation has recently begun to be applied to the design of collaborative technologies, such as multi-agent systems, where a group of intelligent software agents interact to achieve specified goals. An argumentation system would make use of many of the traditional concepts of artificial intelligence such as natural language processing, knowledge representation, and ontology. Natural language is viewed as the most suitable method for interacting with an argumentation system in the area of

each other among the group members. In fact, these unarticulated intentions play a critical role in collaborative decision making by directing argument strategies and explicit statements from behind. While argument networks capture all the explicit statements, some, if not all, of the implicit notions can be captured from the structure of the stated arguments. This will significantly enrich the ability of the argument-based system to capture the content and structure of a discussion within a computationally supporting framework. These views can be extremely useful to a decision maker by facilitating what-if analyses on the group's behavior. Work on this aspect of exploration of implicit assertions is required if effective discussion strategy support mechanisms are to be built.

The collaborative technologies should reflect the social protocols that underlie group communication in terms of strategies and policies for argument exchange and decision making. It is critical to maintain a persistent discussion thread in order to sustain the group's focus throughout the process. Periodic feedbacks on positional assessment to group members would foster creative problem solving and positional strategy development during a collaborative decision-making process. Automated support for conflict resolution and argument assessment is much needed in a fast-emerging facet of corporate collaboration (Raghu et al., 2003). Research on automated negotiation in multi-agent systems to date has focused on two issues: the design of protocols and associated strategies. A negotiation protocol defines the rules of encounter between negotiation partici-

Figure 2. Decision Evolution Process



Source: Ramesh & Whinston, 1994, p. 296

pants. For example, negotiation typically proceeds in a series of rounds, with agents either alternating or simultaneously taking it in turns to make proposals. Protocols, defining when agreement has been reached and what the agreement is, may be designed to have certain desirable properties such as convergence. An agent's key task is to employ a negotiation strategy, which defines how it behaves during negotiation, that maximizes its welfare. Automated negotiation relies on the idea that agents must use the shared protocol and knowledge base in order to resolve issues.

Mathematical logic and classical proof theories (Gensler, 1990; Lorenzen, 1984) do not provide an adequate framework for dealing with arguments. Using binary categories as a basis for rejecting or accepting arguments prevents one from assessing the relative strengths of the arguments. Argumentation support requires an extension of the concepts of inference in first-order logic. The nature of the problem requires inference mechanisms that support the complexities of argument evaluation. In this context, more recent research (Pinkas, 1995; Raghu et al., 2001; Thagard, 1989) has attempted to apply connectionist approaches to argumentation analysis. Connectionist modeling has been viewed as a natural approach to capture human cognition central to the analysis of defeasible logic. It has been used to model defeasible argument in collaborative discussions (Raghu et al., 2001), propositional logic (Pinkas, 1995), causal reasoning (Sun, 1995), and explanatory coherence (Thagard, 1987). From a connectionist perspective, discussion is broken into basic, atomic-level information units along with their *logical* and other *human-intended* relationships. This paradigm can also be used to derive assessments on subsets of a large argument network selectively or on higher-level meta-networks derived by aggregating argument sets from a basic network into meta-units and meta-arcs. Thus the model can provide selectively local views of a comprehensive discussion as well as condensed global perspectives on an entire discussion. While connectionist models do not have the strong theoretical underpinnings of logic-based defeasible graphs, using connectionist models for this purpose has many advantages over methods that utilize simple binary categories of acceptance and rejection (Vreeswijk, 1992). Inference approaches that depart from binary categorizations achieve better sensitivity in argument assessment by indicating the degree of acceptance or rejection of arguments. In addition, such methods enable assignment of weights to the positions and claims. This enables one to capture not only the relations between claims and positions of the members but also the strength of the relation. A dynamic argument should derive its dialectical power by the logical coherence inherent in its structure and by the support it derives from its evidence.

Future Research and Emerging Issues

As organizations have become more distributed geographically, teams and managers have to substitute alternative tools and methods for traditional face-to-face meetings, such as e-mail, bulletin boards, chat rooms, audio-conferencing, and videoconferencing. These tools have benefits but also limitations in simulating face-to-face meetings. A comprehensive approach should be taken to support multiple aspects of group interaction. The primary objective of this chapter is therefore to present a review of the needs of pragmatic and efficient support tools to ease the cognitive burden and guide creative positional and argument strategy development throughout the discussion. This chapter discussed an integrated framework to incorporate the imminent requirements in collaborative technologies by emphasizing the dynamic information models for dialectic decision strategy support. The presented framework is enhanced by domain ontology to create a unified environment for collaborative decision support systems. The main contribution of this chapter is to demonstrate that further decision support functionalities can be embedded in CDM systems that help decision makers better utilize the volumes of information collected through various sources.

We are currently witnessing a convergence of several threads of technology and business imperatives. Other research paradigms such as knowledge management are increasingly being integrated with groupware technology. Both technologically and behaviorally, particular attention will be paid to flexible, dynamic, and open characteristics of the collaborative systems, as well as to issues of cognitive and information overload. Collaborative technologies have begun focusing on providing enterprise collaboration solutions. As global infrastructures span organizational boundaries, support for dynamic work practices and different ways of communication will be extremely important for organizations to support evolving roles and responsibilities assigned to group members in various organizational settings. As the volume of data and human-centered information available to decision makers continues to increase at an accelerating rate, the need to represent information in software-processable formats becomes more apparent. We have identified the key requirements for collaborative decision-making systems in this chapter. These requirements can be translated into a number of functional and nonfunctional requirements, such as security, fault tolerance, safety, etc., for future enterprise collaboration systems.

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Chapter VI

Workflow Collaboration

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Abstract

The chapter focuses on a summary of the contemporary development of workflow management systems in collaborative commerce. The technical facet is demonstrated from perspectives of architectures, standards, and system analysis. The business requirements and application scenarios are exemplified in knowledge sharing, marketing services, and procurement processes. The evaluation approaches are introduced for assessment of system performance and information quality. Conclusions with future trends are illustrated in three aspects — from tangible to intangible access, from internal to external coordination, and from physical to virtual application.

Introduction

Today's dynamic business environment is driving business organizations to compete globally on low costs and great customer services. As a key success factor for effective competitiveness, the management of core business processes, which deliver value to the customers, suppliers, and internal staff, becomes increasingly important. By automating, optimizing, and continuously improving the core business processes, organizations can satisfy their customers, employees, partners, and suppliers by establishing solid competitive advantages.

Since the 1980s, information technology (IT) has provided a wide range of applications supporting automation and management of business processes. Workflow management systems (WFMSs) are the most important of those applications. They provide accurate and consistent information flows between the participants in the business process, smooth integration of the flow of work, timely sharing of data and information during the planning and implementation phases, and harmonious support for the collaboration of work.

Definitions of Workflow and Workflow Management Systems

The workflow concept has evolved from the notion of the process in manufacturing and the office. Such processes have existed since industrialization and are results of efforts to increase efficiency by concentrating on the routine aspects of work activities. They typically separate work activities into well-defined tasks, roles, rules, and procedures, which regulate most of the work in manufacturing and the office (Georgakopoulos et al., 1995).

There are many different views about a process (Basu & Kumar, 2002). First, a process can be viewed as a collection of tasks executed by various resources within a value system comprising one or more interacting units to satisfy customers. Each process takes a specific set of inputs and transforms them into a specific set of outputs. Workflows associated with routine processes are called *production workflows*, while processes associated with nonroutine processes, resulting in possibly novel situations, are called *ad hoc workflows*. On the other hand, a repetitive, predictable process with simple task-coordination rules is called an *administration workflow*. Ideally, business processes should be designed to systematize the routine functions while accommodating exceptional circumstances. Clearly, the specific tasks used to implement a business process may vary from one instance to another. Each such combination of tasks

comprising an enactment of the business process then represents a workflow for this process (Basu & Blanning, 2000).

A second view is from the Workflow Management Coalition (WfMC; <http://www.wfmc.org>). According to the WfMC, a workflow is:

“the automation of a business process, in whole or in part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules.”

This view also assumes that each enactment of the process has a specific workflow and uses the term “work case” to describe each instance. In fact, according to this definition, the terms “workflow management” and “case management” are synonymous. The key feature of this view is its focuses on automation of processes and the implementation of workflow control through a software system called a “workflow engine.”

A third view of a workflow is as a particular type of process. For instance, Baresi et al. (1999) define a “workflowable” process as one with the following characteristics:

- *Predictability*: the process is clearly defined and structured.
- *Repeatability*: the process corresponds to a repeated situation.
- *Distributed*: the process involves several organizational units.
- *Automation*: the process can benefit from automated support.
- *Idling*: the process contains idle periods that can be reduced by automatic checking and deadline management.
- *Opportunity*: the process involves applications that can be easily implemented.

Although these views are quite similar in essence, they are different in specificity. The first one is general and all encompassing, while the third view is more specific in identifying the aspects of business processes that are suitable for automation through IT-based workflow management systems.

Workflow management systems (WFMSs) are a kind of information system specifically used to automate, coordinate, and streamline workflows. Thus a WFMS is a set of tools used to design and define workflows, the environment in which these workflows are executed, and a set of interfaces to the users and applications involved in the workflows.

Benefits of Workflow Management Systems

As a business-process-enabling technology (automation, coordination, and streamlining of business processes), a successful workflow management system may result in:

- higher workload capacity
- reduced process time and improved process quality
- better control of current states and progress of business processes
- eliminated elapsed time between tasks and duplicated tasks
- efficient task delivery and timely and accurate delivery of information
- improved customer and staff satisfaction

For instance, Ader (2000) reports productivity gains from process automation of 5% to 30% and cycle-time reductions of 30% to 80%. According to a Gartner survey, successful workflow projects met or exceeded ROI expectations approximately 89% of the time. Fisher (1997-2000) presents a comprehensive set of cases of successful workflow projects, which illustrate the benefits of workflow management systems.

Introduction to Collaborative Workflow

Business is more than just interactions and transactions. Now that most companies have adopted the Web for transactions and communications, they now plan to use the Web to form a collaborative-centric business model. A *collaborative workflow* is the workflow that automates critical business processes that are not transaction oriented. Collaborative process management and workflow enabling requirements are technologies such as document sharing and management. Collaborative workflow enables greater speed in delivery, quality, and consistency in services and products. Furthermore, they are leveraging the knowledge and information sharing in their employees, customers, and partners for a company to gain a competitive edge. Collaborative workflow systems are becoming more and more popular with the advances of Internet technology and object technology.

Key Literature Review

There has been much research work on workflow and workflow management in the last decade. In this section, we review some of the key literature.

Georgakopoulos, Hornick, and Sleth (1995) provide a comprehensive high-level overview of workflow management methodologies and software products. They discuss the infrastructure technologies that can address the limitations of commercial workflow technology and extend the scope and mission of workflow management systems to support increased workflow automation in complex real-world environments involving heterogeneous, autonomous, and distributed information systems. They also address issues of how distributed object management and customized transaction management can support further advances in commercial workflow management. In their special issue introduction paper, Stohr and Zhao (2001) provide basic definition and frameworks to aid understanding of workflow management technologies and discuss technical and management research opportunities in workflow automation. Alonso, Agrawal, El Abbadi, and Mohan (1997) discuss the functionalities of workflow management systems and the limitations of commercial workflow management systems and elaborate various directions for research and potential future extension to the design and modeling of workflow management systems. Basu and Kumar (2002) provide a perspective on the state of the research in workflow management systems and discuss possible future research in workflow management, with particular emphasis on workflow systems in integrating interorganizational processes and enabling e-commerce solutions.

Besides these survey and overview papers, research has been done in various aspects of workflow and workflow management systems, including concepts of process and workflow, approaches (e.g., Baresi et al., 1999; Medina-Mora, Winograd, & Flores, 1993; <http://www.wfmc.org>, 1996) to workflow specification and modeling (e.g., Basu & Blanning, 2000; Desel & Esparaza, 1995; Ellis, 1999; Fowler & Scott, 1997; Kumar & Zhao, 1997; Marshak, 1994; McCarthy & Dayal, 1989; Murata, 1989; van der Aalst, 1998; Winograd & Flores, 1987); workflow analysis, monitoring, and control (e.g., Chrysanthis & Ramamrithm, 1994; Rusunkiewicz & Sheth, 1995; van der Aalst, 1998; Wachter & Reuter, 1991); distributed interorganizational workflows (e.g., Bauer & Dadam, 1997; Ceri et al., 1997; Kumar & Zhao, 2001; Lindert & Deiters, 1999); integration of workflow with legacy systems and supply chain (e.g., Hartmann et al., 2001; Herring & Milosevic, 2001; Lenz & Oberweis, 2001; van der Aalst & Kumar, 2003); and architecture and enabling technology of workflow management systems (e.g., Monola et al., 1993; Rusinkiewicz & Sheth, 1994; <http://www.omg.org>).

Chapter Structure

This chapter aims at providing a general introduction to collaborative workflow, and some results of our research. The remainder of the chapter is organized as follows. The following section gives a description of workflow management systems, including basic concepts of the business process and process modeling, the architecture of workflow management systems, the standards of workflow management systems, and the enabling technology. Then, we describe workflow management systems in a collaborative environment, including collaborative workflow for internal business processes in e-commerce, collaborative workflow for customer relationship management, and collaborative workflow for supply chain management (coordination, planning, and control). Next, we discuss evaluation of workflow management systems, including assessment of technical requirements and business performance, structure-based performance evaluation, and data/information quality. Finally, we discuss the future directions and conclusions for this chapter.

Workflow Management Systems

Process and Process Modeling

The processes in an organization can be categorized into material processes, information processes, and business processes (Medina-Mora et al., 1993). The scope of a *material process* is to assemble physical components and deliver physical products. *Information processes* relate to automated tasks (i.e., tasks performed by programs) and partially automated tasks (i.e., tasks performed by humans interacting with computers) that create, process, manage, and provide information. *Business processes* are market-centered descriptions of an organization's activities, implemented as information processes and/or material processes. That is, a business process is engineered to fulfill a business contract or satisfy a specific customer need. A workflow may describe business process tasks at a conceptual level necessary for understanding, evaluating, and redesigning the business process. On the other hand, workflows may capture information process tasks at a level that describes the process requirements for information system functionality and human skills.

Process modeling involves capturing a process in a workflow specification. There are two basic categories of process modeling methodologies: *communication-based* and *activity-based* (Marshak, 1994).

The *communication-based methodologies* stem from the Winograd/Flores conversation for action model (Winograd & Flores, 1987). This methodology assumes that the objective of business process reengineering is to improve customer satisfaction. It reduces every action in a workflow to four phases based on communication between a *customer* and a *performer*:

1. *Preparation*: a customer requests an action to be performed or a performer offers to do some action.
2. *Negotiation*: both customer and performer agree on the action to be performed and define the terms of satisfaction.
3. *Performance*: the action is performed according to the terms established.
4. *Acceptance*: the customer reports satisfaction (or dissatisfaction) with the action.

Each *workflow loop* between a customer and performer can be joined with other workflow loops to complete a business process. The performer in one workflow loop can be a customer in another workflow loop. The resulting business process reveals the social networks in which a group of people, filling various roles, fulfills a business process.

Activity-based methodologies focus on modeling the work instead of modeling the commitments among humans. Unlike communication-based methodologies, activity-based methodologies do not capture process objectives such as customer satisfaction.

The communication-based and activity-based workflow models can be combined when process reengineering objectives are compatible with both models (e.g., satisfy the customer by minimizing workflow tasks and human roles).

Workflow Application Architectures

Organizations have different kinds of processes, which may be supported by one or more workflow management systems. The WFMSs are distributed, client/server-based systems on local area networks or a global network with hundreds of thousands of users at thousands of sites and on a variety of hardware platforms. Some workflow systems run on intranets with a WWW interface. The appropriate architectures for WFMSs of the different classes of workflow are very important. There are three basic alternatives (Stohr & Zhao, 2001).

- *Production architecture*: production WFMSs support complex flows and communicate with corporate database and mainframe systems. Usually, a

workflow containing all the documents related to a particular process instance or “case” is generated and presented in turn to each agent that needs to be involved in processing the case. Most existing production WFMSs consist of a single workflow engine using a single database to provide services to a number of users in a client-server architecture.

- *Messaging-based architecture:* administrative WFMSs support less demanding throughput requirements and are often implemented by adding workflow features to the e-mail transportation mechanism. This primarily involves adding electronic form, logging, and work list generation capabilities to the underlying e-mail system. This kind of architecture can easily integrate with other office packages and is suitable for applications such as call centers and customer service.
- *Document-centric architecture:* systems using this architecture add workflow capabilities to document management systems. In corporative workflow, work may be processed by one user passing to another user through an e-mail message containing pointer(s) to the document(s) processed next.

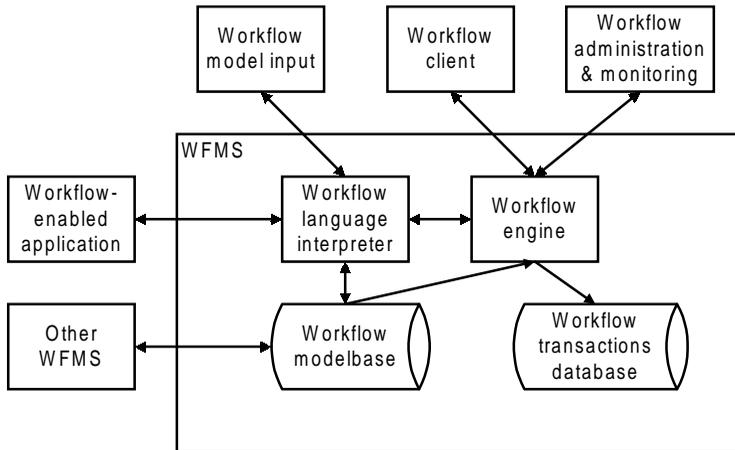
Existing products in each of the three classes are moving rapidly towards Internet-based and object-oriented systems, providing more interoperability between internal applications and the workflow of suppliers and customers in a supply chain. These kinds of systems will be easier to adapt to new requirements and applications.

Workflow Standards

Standards are important factors in making workflow pervasive. In the past few years, significant progress has been made with respect to workflow-related standards, such as WfMC, MAPI-WF, and ODBC, and enabling technologies, such as e-mail, CORBA, and ActiveX/DCOM.

- *WfMC standards:* the WfMC was founded in 1993 and is now considered the primary standard body for the workflow market. The standardization work of the WfMC is centered around the workflow reference model (see *Figure 1*).

Figure 1. Architecture of a Workflow Management System



The reference model specifies a framework for workflow systems, identifying their characteristics, functions, and interfaces. The focus has been on specifying the five APIs (application programming interfaces) that surround the workflow engine. The five APIs are: (1) process definition model and interchange APIs; (2) client APIs; (3) applications invocation interface; (4) workflow interoperability; and (5) administration and monitoring. These APIs provide a standard means of communication between workflow engines and clients (including other workflow components such as process definition and monitoring tools). So far, the WfMC has drafted specifications for all APIs except Interface 3. Most workflow vendors plan to support the WfMC APIs, and some vendors have already demonstrated the WfMC APIs (e.g., for Interface 2) working with their workflow engines.

Workflow interoperability and standards are vital as automation technology becomes more complex, and the coalition's work in this industry is central to keeping up with the rapid progress. On the other hand, workflow standardization is still in its preliminary stage and has a long way to go.

- *MAPI Workflow Framework*: MAPI is a message API standard promoted by Microsoft, and the MAPI Workflow Framework (MAPI-WF) is Microsoft's initiative to the WfMC. The idea is to combine the functionalities of workflow systems and the flexibility of messaging systems so that applications that span both messaging users and business applications can be deployed. It addresses the interoperability issue between messaging

systems and workflow systems. In a message environment, a workflow request (e.g., of Interface 4) can be packaged within some body part of a message. MAPI-WF provides a standard set of body parts and properties so that workflow packages can be delivered to and from the workflow engine. Workflow components (e.g., workflow engines, workflow applications, and workflow tools) that conform to MAPI-WF can communicate via messaging systems such as Microsoft Exchange.

Given the popularity of messaging systems and the influence of Microsoft, MAPI-WF will play an important role in the future. Many workflow vendors have already expressed their intentions to support MAPI-WF in their workflow products.

Technical Requirements and Enabling Technology

To effectively support WFMSs, organizations must evolve their existing computing environments to a new distributed environment that:

- is *component-oriented*, i.e., supports integration and interoperability among loosely coupled components corresponding to heterogeneous, autonomous, and/or distributed (HAD) legacy and new systems;
- supports *workflow applications* corresponding to business or information process implementations accessing multiple HAD systems;
- ensures the correctness and reliability of applications in the presence of concurrency and failures; and
- supports the evolution, replacement, and addition of workflow applications and component systems as processes are reengineered.

Here, the two most important enabling technologies for workflow systems in recent years are object technology and distributed computing technology. Unlike other software systems such as database management systems, workflow systems are distributed and open by nature. To perform a workflow task, the workflow engine needs to invoke remote workflow applications. Object and distributed computing technologies such as CORBA and ActiveX/DCOM are very useful in wrapping, managing, and invoking heterogeneous applications.

Several workflow products have used CORBA and ActiveX/DCOM as transport services to invoke remote applications. There is also research (e.g., Das, Kochut, Millir, Sheth, & Worah, 1997) investigating a CORBA-based workflow

enactment system that supports a scalable software architecture, multi-database access, and an error detection and recovery framework.

Workflow Management Systems in a Collaborative Environment

Organizations are increasingly using electronic means to conduct businesses; thus, they must automate their business processes. The processes include customer-to-business interaction as well as interaction within and between businesses. This naturally leads to collaborative workflows for internal business processes, for customer relationship management, and for supply chain management. In the following section, some of the research and products are described and summarized.

Collaborative Workflow for Business Processes in E-Commerce

Kumar and Zhao (2002) describe various interorganizational electronic commerce applications and discuss their needs for workflow support. Then, they propose a blueprint for XRL, an Extensible Routing Language that enables routing of commercial documents over the Internet and helps in creating truly intelligent documents. XRL is a way to embed routing information in a document so that it can be routed in a variety of different ways. These basic constructs, straight sequence, parallel, and flexible sequence routing, can then be combined together to develop more complex routing schemes. This routing language is simple, yet powerful enough to support flexible routing of documents in the Internet environment.

Van der Aalst and Anyanwu (1999) present an approach for designing interorganizational workflows that, on one hand, allows full cooperation and collaboration of business partners towards the completion of a business process while, on the other hand, allows business partners to preserve their autonomy. The workflow modeling is based on the Petri net formalism. Interorganizational workflows cross-organizational borders often results in conflicting requirements. On one hand, the overall workflow should be managed and coordinated to avoid stagnation and errors. On the other hand, local autonomy is needed to enable each of the business partners to handle their part of the workflow as effectively and efficiently as possible. The approach for designing

interorganizational workflows is a four-step process that involves creation of a public process, partitioning the public process amongst the partners, and allowing for modification by the individual partners of their parts of the process to create private processes.

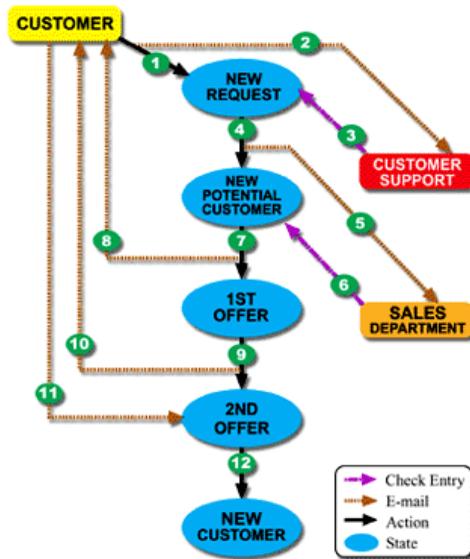
DST's Automated Work Distributor (AWD) is an advanced, intelligent workflow and customer relationship management system. With AWD's workflow-enabled e-commerce solutions, a virtual business environment can be created while managing workflow more efficiently and taking greater control of customer relationships. AWD's e-commerce solutions include AWD/eMail®, which integrates inbound and outbound correspondence e-mail directly into AWD workflow (DST Systems, 2003).

Collaborative Workflow for Customer Relationship Management

A case study reported by Microsoft (1999) about the Salzburg municipal authority of Austria shows increased administration efficiency and improved relations with citizens by a workflow system integrated with geographic information systems and document management system. With its File 2000 project, the Salzburg municipal authority is realizing its IT challenge to implement flexible business-process solutions, and establish and run knowledge databases and networks. The first phase of the project, Build Info-3, was completed in 1999. It incorporated a host-oriented building procedure switching over to a process-oriented Microsoft Windows NT-based citizen relationship management (CRM) workflow system, with integrated geographic information systems (GIS) and document management. By 2000, some 80% of authority business will have workflow support on the network, spanning 800 PC workstations in six locations.

Clients of Capital IQ can integrate Capital IQ market intelligence and analytics modules into their existing CRM and workflow platforms to help enhance their idea generation processes and make their platforms more robust for their users. Integrating user-relevant data and tools with an existing relationship management platform drives user adoption, which is the key success factor for CRM platforms. These solutions consist of single sign-on, HTML, and/or XML Web services integrations (Capital IQ, 2003). IMA (2003) also intends its service, AbsoluteCRM, to provide an easy integration of any online form into a ready-to-use CRM workflow system. Active Report is the application that powers AbsoluteCRM. Within Active Report every submitted request will go through various states depending on the actions taken. Every state will have a resulting state based on this action. *Figure 2* shows the various states (ovals) and actions (black arrows) taken on a new customer request.

Figure 2. Workflow in Active Report for an Example of a New Customer Request



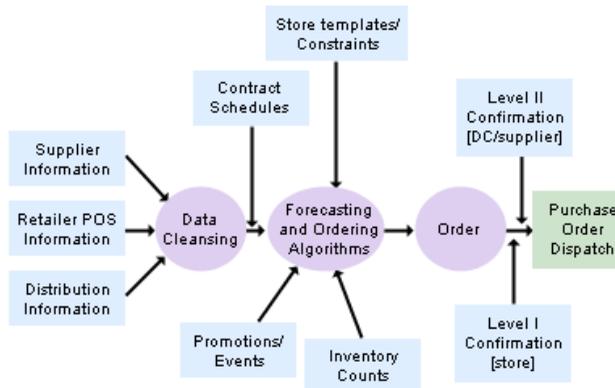
Source: <http://www.new-object.com/crm/>

IBM Multipayment Framework in WebSphere Commerce Payments offers payment-management functions while supporting back-end business functions like ERP, CRM, workflow, and custom-written applications. Sellers can store and capture payment information such as buyer account numbers and financial routing numbers to use in executing transactions. The framework can perform payment-management functions using a variety of currently supported payment instruments, including payment cards, and new payment instruments introduced in the marketplace (IBM, 2003).

Collaborative Workflow for Supply Chain Management

DemandAnalytX is a Web-based application designed to receive and share information and facilitate communications and approvals throughout the customer organization and with trading partners to support collaborative business (SupplyScience, 2003). DemandAnalytX fully automates the replenishment process to avoid constant parameter entry and review and the resulting frustrating communications bottlenecks among stores, distribution centers, and suppli-

Figure 3. Enterprise Workflow of the DemandAnalytX Solution



Source: <http://www.supplyscience.com/products/workflow.htm>

ers. *Figure 3* illustrates the enterprise workflow of the DemandAnalytX solution. Once information is gathered and processed, demand is forecast, and the order is modeled, the actual ordering process will take place. DemandAnalytX implements the process of order restriction and order confirmation defined in the contract. Thus the confirmation workflow is customized to suit the needs of demand-chain participants. The order confirmation is completed via the Web client and PDAs, as appropriate.

The TradeMatrix Network is divided into the TradeMatrix Network client and the TradeMatrix Network server (i2, 2000). The TradeMatrix Network server is also referred to as the integration server. The TradeMatrix Network client is the interface exposed to the EAI vendors, and all of the interface discussions in the following sections refer to the TradeMatrix Network client. *Figure 4* shows the TradeMatrix Network architecture.

Evaluation of Workflow Management Systems

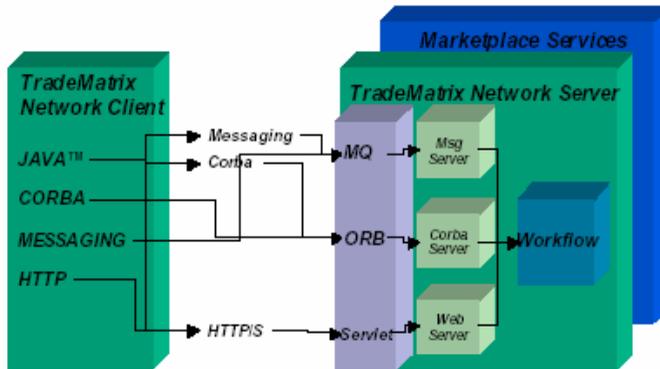
The evaluations of the workflow management system can be from the perspectives of business, system, and use. The *business issues* cover the business needs, cost, and ROI, and the scope can be a department, an enterprise, or a supply chain. The *system performance* includes system requirements, speed, scalability, flexibility, etc., and the focus can be information presentation (i.e., user interfaces), information handling (i.e., databases), and information process-

software functionality requirements. They establish a catalogue of evaluation criteria, summarize the huge amount of criteria into smaller classes (criteria categories), and order the classes in a semantically structured directory. A tool implementing the evaluation framework is also described in their work.

Perry, Porter, Votta, and Wade (1996) notice that most software engineering research has focused on improving the quality or reducing the cost of software but has ignored the need to reduce cycle time (the calendar time needed to develop and deliver a product.) Because short time-to-market can be a significant advantage in rapidly changing and highly competitive markets, many companies are demanding tools and practices that build quality software faster. To help understand the importance of reducing cycle time, consider the software inspection process. Although this is an expensive process, its cost is often justified on the grounds that, since the longer a defect remains in the system the more expensive it is to repair, the cost of finding defects today must be less than the cost of repairing them in the future. Many people believe that workflow and process automation tools can significantly reduce cycle time. They develop workflow tools that allow distributed groups to execute a wide variety of software inspection processes. More importantly, they are using this technology in a live software development project to support controlled experiments exploring how process structure affects cycle time.

Carlsen, Krogstie, Slyberg, and Lindland (1997) propose a framework for evaluating quality in process modeling languages (PMLs) and models. It is applied to a representative sample of flexible workflow products and prototypes. They study the properties of the various products' underlying PMLs and derive their first-cut ontology, or meta-model. The framework, in particular, addresses model comprehensibility but also includes social quality and knowledge quality; it conforms to a social constructivist approach to process support. The framework is based on the following concepts: A *business process* is represented in a *business process model* expressed in a *process modeling language* (PML). The model is subject to *audience interpretation* from various human *stakeholders* and technical actors (i.e., tools). Some of the stakeholders contribute to modeling and are called *participants*. They reflect their *participant knowledge* of the business process in the model. Relationships between these concepts give a framework for understanding quality related to business process modeling. InConcert, TeamWare Flow, and Obligations as dynamic approaches and Action Workflow and WooRKS as static approaches are used for the product survey. A set of desirable flexibility features for workflow systems was derived: wide stakeholder model orientation; extensible metalanguages (physical quality); flexible error handling support (syntactic quality); quick turnaround for model changes; variety and modifiability in support for model fragments (semantic quality); animation, simulation, and explanation generation to increase comprehensibility; application of shared workspaces to decrease model complexity

Figure 4. TradeMatrix Network™ Architecture



Source: <http://www.i2.com/assets/pdf/F50FAE91-68B8-11D4-9EDB-0008C7FA726A.pdf>

ing (i.e., system functions). The *usability* concerns the measurement of ease of use, usefulness, effectiveness, etc., and the focus can be a single user, homogeneous group, or heterogeneous group.

Another view of evaluation issues focuses on what, how, or what/how to do the assessment of workflow management systems. This may include the model (e.g., Petri-net-based WFMS) and its related evaluation methods, how to do the data collection (e.g., time logs), and where/what to do on evaluation (e.g., processes in various applications). On the other hand, there is a lot of research on information quality (IQ) in recent years, and it is starting to get attention and applications in the area of information systems. Combined with the traditional service quality assessment and other performance measurements, IQ can be a framework for the process-oriented information systems applied in the e-business. In addition, the impact study of workflow management systems is also important to investigate the suitability of the extension of the systems' usage in new development and applications.

Assessment of Technical Requirements and Business Performance

Berger, Ellmer, and Quirchmayr (1997) describe a project focusing on the evaluation of workflow management systems for a large Austrian bank. They first classify the WFMS requirements into supplier requirements, system platform requirements, software requirements, software quality requirements, and

(pragmatic quality); argumentation support (social quality); systematic approach to organizational learning and knowledge creation; structuring of process models for simultaneous reuse and comprehensibility (knowledge quality); and suitable ontology for wide range of processes as well as process stakeholders (language quality). None of the surveyed products are flexible along all these dimensions, and some features are not covered by any product.

A white paper of Ultimius (2002) provides a method for categorizing and evaluating workflow automation products — first it provides a clear definition of workflow so that the readers can understand what it is and what it is not; second, it provides a method of categorizing workflow products into one of two types; third, it defines and clarifies the relationship between business process management (BPM), WFA, and EAI; and finally, it provides a systematic method of evaluating various workflow products by comparing their capabilities and completeness. When evaluating workflow products, the two key areas that must be considered are: (1) capability: how capable is the product to meet workflow automation requirements and (2) completeness: how complete is the product with respect to workflow. By evaluating products against these key features, you can develop a capability/completeness matrix. Each quadrant of the matrix represents a different type of products: (1) workflow enablers; (2) workflow engines; (3) application-specific workflow; and (4v) general-purpose workflow applications.

Structure-Based Performance Evaluation

Lin, Qu, Ren, and Marinescu (2002) propose a stochastic Petri nets workflow model (WF-SPN), which is the extension of WF-net. Based on this model, performance equivalent formulas are defined for four basic routing patterns — *sequential routing*, *parallel routing*, *selective routing*, and *iterative routing* — of the workflow system. The main performance analysis technique for workflow is Markovian analysis. The performance analysis method is: first, based on WF-SPN, transforming each basic routing subset (pattern), which consists of a number of tasks, into one task, and this task has the same time performance with the original subnet so as to simplify the original workflow system; then, for the simplified workflow system, repeating the first step until simplifying the workflow system to one task with the same time performance as in the original workflow system. The complexity of this workflow performance analysis method increases linearly with the increase of the scale of the workflow model. An example illustrates the applicability and efficiency of the method for real-world problems.

Salimifard and Wright (2002) propose a modeling methodology for workflow management systems based on colored Petri nets. It combines different model-

ing views and integrates a process model and an organizational model. Processes and resources are modeled at the same abstraction level. A process is decomposed into task structures, whilst human resources are considered at role level. Activity-based costing (ABC) is combined with classical temporal analysis of workflow. The methodology is supported using the software tool Design/CPN for both modeling and simulation. The suitability of the method has been tested using an application example.

Dehnert, Freiheit, and Zimmermann (2000) introduce a methodology for the modeling and performance evaluation of workflow processes, which integrates deterministic and stochastic durations. The approach is not limited to the functional aspects but includes a resource description as well. Evaluation of the performance is facilitated by associating stochastic, deterministic, or zero firing delays with transitions. Basic quantitative measures like the throughput, utilization, queue length, processing time, and others can be computed either by direct numerical analysis or discrete event simulation. This is done using methods developed for extended deterministic and stochastic Petri nets (eDSPNs) because the stochastic process underlying both model types belongs to the same class. The evaluation of the model can be used to answer questions such as:

- How many documents can be processed per week with the modeled organization?
- What is the mean time for a case to be finished?
- How big is the utilization of the resources?
- What are the bottlenecks?
- How much time does a document spend during processing, waiting, or being transported?
- How will the above numbers change if the available staff decreases, e.g., due to holidays?

Van der Aalst and van Dongen (2002) develop techniques using “workflow logs,” which contain information about the workflow process as it is actually being executed. They extend existing mining techniques to incorporate time and assume that events in workflow logs bear time stamps, which is used to attribute timing such as queue times to the discovered workflow model. The approach is based on Petri nets, and timing information is attached to places. They also present the workflow-mining tool EmiT, which translates the workflow log of several commercial systems to an independent XML format. Based on this format the tool mines for causal relations and produces a graphical workflow model expressed in terms of Petri nets.

Data and Information Quality

Ballou, Wang, Pazer, and Tay (1998) present an information-manufacturing model that can be used to determine the timeliness, quality, cost, and value of information products. The model has a predefined set of data units that undergo predefined processing activities. The work is customer driven in that the value of the information products manufactured by the system is determined by the customer of information products. They apply the model to a mission-critical information-manufacturing system found in a major optical products company, Optiserve. One of the benefits of the information-manufacturing model is its ability to model the impact on an information system of a changed environment and the efficacy of various options for addressing these changes. This research is particularly timely in light of the industrial trend toward total quality management and business process reengineering. At the intersection of these driving forces is information quality.

Wang, Lee, Pipino, and Strong (1998) further study the issues of managing the information as a product instead of information by-product. To treat information as a product, a company must follow four principles:

- Understand consumers' information needs.
- Manage information as the product of a well-defined production process.
- Manage information as a product with a life cycle.
- Appoint an information product manager (IPM) to manage the information processes and resulting product.

Redman (1998) summarizes the impact of poor data quality in typical enterprises as operational impacts, typical impacts, and strategic impacts. Creating awareness of these issues within an enterprise is the first obstacle that practitioners must overcome when implementing data quality programs. The tangible impacts, such as customer dissatisfaction, increased cost, ineffective decision making, and the reduced ability to make and execute strategy, are bad enough. The intangible impacts, including lower morale, organizational mistrust, difficulties in aligning the enterprise, and issues of ownership, may be even worse.

Orr (1998) describes a number of general data-quality rules one can deduce from a feedback system view of information systems:

- Unused data cannot remain correct for very long.
- Data quality in an information system is a function of its use, not its collection.

- Data quality will, ultimately, be no better than its most stringent use.
- Data quality problems tend to become worse as the system ages.
- The less likely some data attribute (element) is to change, the more traumatic it will be when it finally does change.
- Laws of data quality apply equally to data and metadata (the data about the data).

Wang (1998) points out that researchers and practitioners alike have moved beyond establishing information quality as an important field to resolving IQ problems — problems ranging from IQ definition, measurement, analysis, and improvement to tools, methods, and processes. He also describes in detail that total data quality management (TDQM) at MIT develops the concepts, principles, and procedures for defining, measuring, analyzing, and improving information products, and an IQ survey software instrument for information quality assessment.

Data quality is a multidimensional concept. Companies must deal with both the subjective perceptions of the individuals involved with the data and the objective measurements based on the data set in question. Subjective data-quality assessments reflect the needs and experiences of stakeholders: the collectors, custodians, and consumers of data products. If stakeholders assess the quality of data as poor, their behavior will be influenced by this assessment. One can use a questionnaire to measure stakeholder perceptions of data quality dimensions. Many health-care, finance, and consumer product companies have used one such questionnaire, developed to assess the data quality dimensions listed in *Table 1* (Pipino, Lee, & Wang, 2002). They also describe the subjective and objective assessments of data quality and present three functional forms — simple ratio, min or max operation, and weighted average — for developing objective data-quality metrics. Using the subjective and objective metrics to improve organizational data quality requires three steps:

- Performing subjective and objective data quality assessments.
- Comparing the results of the assessments, identifying discrepancies, and determining root causes of discrepancies.
- Determining and taking necessary actions for improvement.

This framework is also extended for the information quality benchmarks summarized as follows (Kahn, Strong, & Wang, 2002). They present a methodology and test its efficacy through a rigorous case study. The main contribution of the research is:

Table 1. Data Quality Dimensions

Dimensions	Definitions
Accessibility	the extent to which information is available, or easily and quickly retrievable
Appropriate Amount of Information	the extent to which the volume of information is appropriate for the task at hand
Believability	the extent to which information is regarded as true and credible
Completeness	the extent to which information is not missing and is of sufficient breadth and depth for the task at hand
Concise Representation	the extent to which information is compactly represented
Consistent Representation	the extent to which information is presented in the same format
Ease of Manipulation	the extent to which information is easy to manipulate and apply to different tasks
Free-of-Error	the extent to which information is correct and reliable
Interpretability	the extent to which information is in appropriate languages, symbols, and units, and the definitions are clear
Objectivity	the extent to which information is unbiased, unprejudiced, and impartial
Relevancy	the extent to which information is applicable and helpful for the task at hand
Reputation	the extent to which information is highly regarded in terms of its source or content
Security	the extent to which access to information is restricted appropriately to maintain its security
Timeliness	the extent to which the information is sufficiently up-to-date for the task at hand
Understandability	the extent to which information is easily comprehended
Value-Added	the extent to which information is beneficial and provides advantages from its use

Source: Pipino et al. (2002)

- Developing a two-by-two conceptual model for describing IQ. The columns capture quality as conformance to specifications and as exceeding consumer expectations, and the rows capture quality from its product and service aspects. We refer to this model as the product and service performance model for information quality (PSP/IQ), as shown in *Table 2*.
- Integrating the IQ dimensions identified in our previous research into the PSP/IQ model, as shown in *Table 3*. Since a measurement instrument for the IQ dimensions has already been developed, this integration provides the basis for IQ assessment and benchmarks within the context of the PSP/IQ model.

Demonstrating the efficacy of the PSP/IQ model in three large health-care organizations.

Table 2. Aspects of the PSP/IQ Model

	Conforms to Specifications	Meets or Exceeds Consumer Expectations
Product Quality	<u>Sound Information</u> The characteristics of the information supplied meet IQ standards.	<u>Useful Information</u> The information supplied meets information consumer task needs.
Service Quality	<u>Dependable Information</u> The process of converting data into information meets standards.	<u>Usable Information</u> The process of converting data into information exceeds information consumer needs.

Source: Kahn et al. (2002)

Table 3. Mapping the IQ Dimensions into the PSP/IQ Model

	Conforms to Specifications	Meets or Exceeds Consumer Expectations
Product Quality	<u>Sound Information</u> <ul style="list-style-type: none"> • Free-of-Error • Concise Representation • Completeness • Consistent Representation 	<u>Useful Information</u> <ul style="list-style-type: none"> • Appropriate Amount • Relevancy • Understandability • Interpretability • Objectivity
Service Quality	<u>Dependable Information</u> <ul style="list-style-type: none"> • Timeliness • Security 	<u>Usable Information</u> <ul style="list-style-type: none"> • Believability • Accessibility • Ease of Manipulation • Reputation • Value-Added

Source: Kahn et al. (2002)

Future Directions and Conclusions

From the impacts of technology evolution, business process extension, and digital economy drive, the undergoing development of workflow management system goes into three directions — *from tangible to intangible*, *from internal to external*, and *from physical to virtual*.

1. *From tangible to intangible*: The workflow management system evolves from being based on a stand-alone PC, to local network connected, to Internet based, and most recently to mobile device platform. The accessi-

bility has been enhanced through the communication stemming from physical linkage to wireless connection.

2. *From internal to external:* The main focus of workflow management has been extended from synchronization of intra-organizational functions into coordination of interorganizational activities. In addition to the general organization of front-office and back-office tasks, the scope has been broadened to production planning, scheduling and control, distribution, retailing, etc.
3. *From physical to virtual:* In parallel to the vertical integration in the supply chain, workflow management also reaches the point of horizontal integration, as in e-hub and e-market, that triggers both forward and backward aggregation in e-business. The management of highly dynamic grouping increases the added value for the coordination of information flows.

From Tangible to Intangible: Mobile Workflow

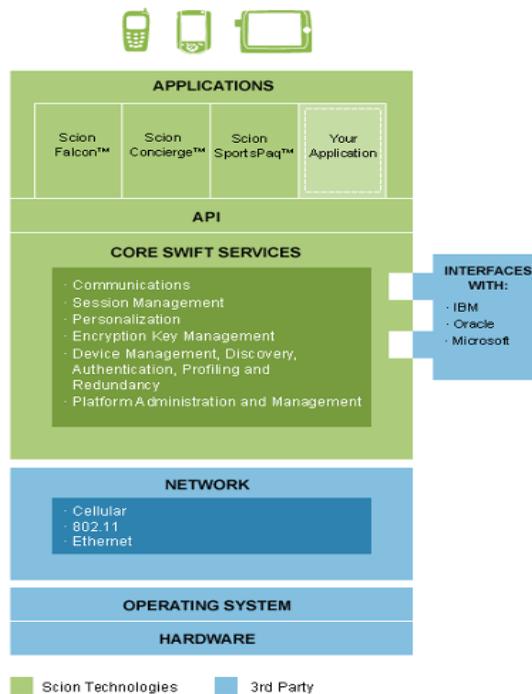
Due to the short cycle of the development in information technology, workflow management systems have been evolved from personal computer based to network/Internet connected and recently to wireless platform. The first task is to decide the models and protocols in order to migrate the processes onto the mobile devices, such as mobile phone and PDA (personal digital assistant). However, the new technology is not mature enough (or will never be) to replace the existing systems, so platform compatibility becomes another concern in the mobile workflow.

Workflow technology has recently been employed not only within businesses but also as a framework for implementing services over the Internet. With the advancement and spreading of various mobile technologies and infrastructures, there is increasing demand for mobile users to connect to workflow management systems (WFMSs). The basic requirement is to support SMS (Short Message Service), WAP (Wireless Application Protocol), and Web browsers on PDAs, in addition to regular Web browsers on PCs. As the capabilities and bandwidth of these mobile devices are significantly inferior to computers over regular Internet connections, workflows have to be adapted to accommodate these limitations (Chiu, Cheung, & Kafeza, 2002). Instead of redesigning or adapting workflows in an ad hoc manner for different kinds of platforms, they propose a framework of workflow adaptation for mobile users based on three tiers of views: user interface views, data views, and workflow views. User interface views provide alternative presentations of inputs and outputs. Data views summarize data over limited bandwidth and display them in different forms. Chiu et al. introduce a novel approach of applying workflow views to mobile workflow

adaptation, where mobile users may execute a more concise version or modified procedures of a business process. The workflow view also serves as the centric mechanism for integrating user interface views and data views. They also demonstrate the feasibility of the approach by extending the flexible Web-based WFMS E-ADOME into ME-ADOME.

Mobile workflow is now only at a starting stage. The WHAM (workflow enhancement for mobility) prototype supports a mobile workforce and applications in a workflow environment, with a focus on network connectivity and the mobility of workflow resources (Jing et al., 2000). Tjoa et al. (2000) introduced a Java Border Service Architecture, which is an abstract layer between the presentation and application logic of an application, to handle mainly user interface issues of mobile devices, using workflow as an example. As for commercial products, Staffware (2000) has recently introduced WAP Business Process Server. However, all of them do not support platform-specific workflow adaptation or integrated platform-independent solution. Neither do they support view mechanisms.

Figure 5. Wireless Technology Solution of Scion Communications



Source: http://www.scioncommunications.com/services_tech.html

Scion Communications (2003) examines the business processes and operational challenges of specific industries and develops applications to mobilize the workforces and conduct critical tasks more efficiently with wireless technology. Recognizing that many businesses require tailored mobile applications at an affordable price, Scion Communications has developed a wireless peer-to-peer platform that minimizes development costs and timelines. The wireless platform — SWIFT (Scion Wireless Information Flow Technology) — handles the key communication, discovery, and device management components of wireless applications (e.g., encryption, device authentication), which minimizes development cycles and cost. *Figure 5* shows the wireless technology solution of Scion Communications.

From Internal to External: Reactive Planning and Scheduling

Senkul, Kifer, and Toroslu (2002) model the scheduling of workflows as a problem of finding a correct execution sequence for the workflow tasks, i.e., execution that obeys the constraints that embody the business logic of the workflows. Research on workflow scheduling has largely concentrated on temporal constraints, which specify correct ordering of tasks. Approaches in this area are typically based on temporal logic, Petri nets, and concurrent transaction logic. Another important class of constraints — those that arise from resource allocation — has received relatively little attention in workflow modeling. Examples of such resources include physical objects, like workshop devices that a task might need in order to accomplish its goal, or intangible resources, such as time and budget. Since typically resources are not unlimited and cannot be shared, scheduling of a workflow execution involves decisions as to which resources to use and when. In their work, a framework for scheduling workflows whose correctness is given by a set of resource allocation constraints is presented. This framework integrates concurrent transaction logic (CTR) with constraint logic programming (CLP), yielding a new logical formalism, which is called concurrent constraint transaction logic (CCTR).

Smith, Hildum, and Becker (1999) examine the workflow management process from a scheduling perspective. Recognizing that effective workflow management requires an ability to efficiently allocate limited resources to tasks over time, they concentrate on characterizing this domain as a continuous distributed scheduling problem and on understanding the requirements and opportunities for providing workflow-scheduling support within multi-agent environments. The research goals are twofold: (1) to relate the characteristics of the workflow

management problem to scheduling models previously developed for other domains and (2) to identify the issues and challenges surrounding the application of previously developed scheduling technology to this problem.

In a workflow, tasks executing on autonomous, heterogeneous systems are coordinated through data and control constraints. An important challenge in workflow management is the scheduling of actions and operations performed by the concurrently executing tasks. Jensen, Wallace, and Soparkar (1997) apply the techniques of supervisory control theory to construct a scheduler that allows the best possible approximation to the desired class and provides an effective means to model several workflow systems and to create scheduling mechanisms to manage them.

Singh, Meredith, Tomlinson, and Attie (1995) present an approach of event algebra in which dependencies characterizing workflows can be declaratively expressed and by which workflows can be efficiently scheduled. They also show how to symbolically process these dependencies to determine which events can or must occur and when. Attie, Singh, Emerson, Sheth, and Rusinkiewicz (1996) formalize intertask dependencies using temporal logic. This involves event attributes, which are needed to determine whether a dependency is enforceable and to properly schedule events. Each dependency is represented internally as a finite state automaton that captures the computations that satisfy the given dependency. Sets of automata are combined into a *scheduler* that produces global computations satisfying all relevant dependencies and thus enacts the given workflow.

In most available workflow systems, performance and reliability problems arise because of a centralized architecture. Agents offer a new way to decentralize and scale a workflow system. In an agent-based workflow system, the agents perform, coordinate, and support the whole workflow or parts of the workflow. However, there are some problems that can be solved simply in centralized workflow systems but are hard in agent-based workflow systems, for example, task scheduling (Stormer, 2000). Sewell and Tan (1997) use a market-based mechanism for dynamic scheduling in workflow automation. The WorkWeb System is an expanded workflow system that is able to manage and control office resources. The BPT agent in the system autonomously manages each workflow process instance, trying to acquire the necessary resources to complete it in time. The WorkWeb System also provides visual interfaces to manage and control office goals and several workflow replanning algorithms to handle exceptional cases (Tarumi, Kida, Ishiguro, Yoshifu, & Asakura, 1997).

From Physical to Virtual: E-Service, E-Market, and E-Hub

The main strengths of a B2B exchange are benchmarked on its ability to provide support for negotiations and returns on the value for time and money; the flexibility in terms of arbitrations; ease of use; and, top of all, managing the manageability, i.e., administering the activities and maintaining customer relationships. The highly collaborative process of creating a request or an offer is greatly facilitated by Hermes, which tracks current status and ownership as users contribute and approve content. The equally collaborative process of exchanging requests and offers between organizations is also facilitated and expedited by tracking communications and maintaining a full audit trail of all information exchanged between parties (COMPUSOL, 2003).

Lack of application integration limits the benefits of e-markets, but vendors are addressing the problem. IBM adds XML compliance to its WebSphere application server. The new product, WebSphere B2B Integrator, is optimized for online marketplaces. The software adds functions such as dynamic pricing, workflow management, and the ability to generate requests for proposals (Sweat, 2000). E-Hub is an Oracle consulting solution aimed at allowing customers to create e-service hubs. A key requirement of the e-hub is to integrate applications. Oracle9iAS InterConnect is a component of E-Hub that handles this integration requirement. Oracle Workflow provides business process management. Integration of Oracle Workflow makes the enterprise-wide business-process-driven integration feasible. InterConnect and Workflow work cooperatively at design time and runtime, sharing metadata, events, and other services (Oracle, 2003).

Microsoft (Microsoft .Net Enterprise Servers, 2001) describes a case study of e-hub applications for PartnerCommunity.com. Two tightly integrated applications built on the BizTalk Server 2000 e-commerce platform provide PartnerCommunity.com customers with comprehensive functionality for effective partner management. The applications are made up of a Web-portal application that supports collaboration and a B2B document and message exchange service. The two applications work together within the e-hub infrastructure of PartnerCommunity.com. Each application was developed on a multi-tier platform. The Web portal utilizes the Microsoft .NET Enterprise Server model of a three-tier application. It was built using Microsoft Active Server Pages and runs on Microsoft Windows 2000 with Internet Information Services (IIS), Microsoft SQL Server, and Microsoft Site Server. The solution makes extensive use of the BizTalk Extensible Markup Language (XML) Framework and XML technologies. It also incorporates component object model

(COM) and COM+ components for business rules and the access-data tier. The document and message exchange service makes further use of Microsoft products — incorporating BizTalk Orchestration to control transaction processing workflow and Microsoft Message Queue Service (MSMQ) for third-party integration and asynchronous communication channels.

An e-market is an electronic trading community made up of buyers and sellers with common needs. E-markets include auctions, exchanges, and multi-supplier online catalogs. E-markets typically offer a wide variety of ancillary services required by the members of the trading community, such as authenticating buyers and sellers and streamlining procurement workflows, risk management, settlement services, conflict resolution services, and logistics services (Seybold, 2000).

An e-market contains five fundamental elements: content, commerce, coordination, community, and connectivity (Lubinsky, 2001):

- *Content*: aggregate, normalize, and standardize catalog information for customers; provide search and content filtering capability; create member profiles.
- *Commerce*: provide dynamic pricing, transaction, payment, and global trade capabilities.
- *Coordination*: enable approval workflow and negotiation: exchange, auctions, reverse auction, dynamic contracts, order tracking, etc.
- *Community*: build loyalty and repeated use through chat, discussion, shared workspaces, and e-mail.
- *Connectivity*: integrate back-end systems, trading partner systems, and other e-markets for seamless information flow.

The core e-market technology includes database, application server, portal, Lightweight Directory Access Protocol (LDAP), and process support. Depending on the complexity required for process support, process support is an execution platform for long-running processes and can be based on either an enterprise application integration (EAI) solution or workflow engine. The business process functions as part of the infrastructure for the e-market. Business process servers, whether they are EAI servers or workflow engines, usually include tools for building and implementing business processes and rules (Lubinsky, 2001).

Conclusions

E-business and workflow management are integrated as a result of evolution for natural amalgamation, and both concern the information flow in application processes. This chapter focuses on the summary of the current status of workflow management systems in collaborative commerce and highlights the applications and development trends as well. The technical facet is illustrated from the perspectives of system architectures, standards, and requirements. The business applications are exemplified in knowledge sharing, marketing service, and procurement processes in supply chain management. The assessment methods are described for system performance and information quality, and conclusions with future trends are illustrated in three aspects — from tangible to intangible, from internal to external, and from physical to virtual.

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Chapter VII

Knowledge Networking for Collaborative Commerce

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Abstract

This chapter aims to describe interorganizational “knowledge networks” and demonstrate how they have ushered in a new paradigm of collaborative business by forging links between internal and external knowledge and information resources. The overall aim is to classify and review various approaches in interorganizational knowledge networking whose objectives may span a multitude of needs: from “loose” information sharing that may be not connected to financial transactions between the networking organizations to “tight” knowledge exchanges that are related to commercial transactions and enable the creation of value from leveraging the interchange of knowledge assets.

financial transactions between the networking organizations, to “tight” knowledge exchanges that are related to commercial transactions and enable the creation of value from leveraging the interchange of knowledge assets.

The present chapter is organized as follows. After two sections on the importance on knowledge and knowledge management and on the issues inherent in managing knowledge within collaborative commerce efforts, it presents a typology of knowledge sharing networks and analyses the technologies for enabling the operation of knowledge networks. It then presents and analyses (using a validated knowledge management framework) two toolkits for interorganizational knowledge networking. It discusses the benefits and challenges associated with interorganizational knowledge sharing and concludes with future trends and emerging models for knowledge networks.

Knowledge Management and Knowledge Networking

Knowledge and Knowledge Management

The task of developing and applying *knowledge management* (KM) as a new discipline is a challenging endeavor. This new discipline must successfully respond to the diverse needs of companies in a timely fashion. However, despite a wealth of books, reports, and studies, neither researchers nor practitioners have an agreed definition of knowledge management. The term is used loosely to refer to a broad collection of organizational practices and approaches related to generating, capturing, and sharing knowledge that is relevant to the organization’s business. There are many different interpretations as to what it exactly means and how to best address the emerging questions about how to effectively use its potential power; see, e.g., Nonaka and Takeuchi (1995), Davenport and Prusak (1998), Edvinsson and Malone (1997), and Wiig (1995). Some would even argue that knowledge management is a contradiction in terms, being a hangover from an industrial era when control modes of thinking were dominant.

Whatever the term and the definition employed to describe it, knowledge management is increasingly seen as signaling the development of a more organic and holistic way of understanding and exploiting the role of organizational knowledge in the processes of managing and doing work.

But what would *knowledge* be in an organizational setting? Debates and discussions about the definition of knowledge abound. In everyday language, it

Introduction

In today's hyper-competitive global marketplace, it is pivotal for enterprises to manage not only tangible resources but also to exploit their intangible knowledge assets. A consequent outcome of this realization has been the surge of interest in knowledge management. Knowledge management has been an item of strong interest in recent times in the research community (see, e.g., Alavi & Leidner, 1999; Davenport & Prusak, 1998; Nonaka, 1991, 1994; Nonaka & Takeuchi, 1995; Zack, 1999). However, research addressing the management of knowledge across organizational borders can best be described as sparse (see, e.g., Holtshouse, 1998). To date, there is yet to be a significant undertaking that looks at issues in managing knowledge across borders. This is unfortunate when looking at the increasing evidence that organizations are aware that they are part of a complex network of connections with their partners and customers. This network is not merely a supply chain or a financial connection — it is based on an increasingly intimate sharing of information and knowledge. The search for innovation and competitive advantage is increasingly focused on the cultivation and exploitation of these knowledge chains.

On the other hand, information and knowledge exchange across the organizational boundaries becomes crucial within the area of collaborative commerce. The concept of collaborative commerce, and more generally collaborative business, has been recently introduced to encompass: all stages of collaboration between organizations from cradle to grave (initiation, management, operational life, and dissolution); all phases of extended products' life cycle (conception, design, manufacturing, usage, maintenance, and end of life); all forms of collaboration (ad hoc, mediated, and planned); and all enterprise assets in any type of business network (people, ICT systems, processes, and knowledge assets).

The task of developing and managing knowledge assets in the collaborative business environment poses new challenges both to knowledge management theorists and practitioners. Companies at the forefront of these initiatives are extending the notion of the virtual community to include stakeholders outside the company (Ovum, 1999). This means sharing a collaborative engineering environment with suppliers and business partners or forging new relationships with customers through regular e-mail contact or user discussion forums.

This chapter aims to describe interorganizational “knowledge networks” and demonstrate how they have ushered in a new paradigm of collaborative business by forging links between internal and external knowledge and information resources. The overall aim is to classify and review various approaches in interorganizational knowledge networking whose objectives may span a multitude of needs: from “loose” information sharing that may be not connected to

has long been the practice to distinguish between information — data arranged in meaningful patterns — and knowledge — something that is believed, that is true (for pragmatic knowledge, that works), and that is reliable. The interchangeable use of information and knowledge can be confusing if it is not made clear that knowledge is being used in a new and unusual sense and can seem unscrupulous insofar as the intent is to attach the prestige of knowledge to mere information. It also tends to obscure the fact that while it can be extremely easy and quick to transfer information from one place to another, it is often very difficult and slow to transfer knowledge from person to another.

A definition that is suitable for our purposes is the one given by Davenport and Prusak (1998), who define *knowledge* as:

“a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms.”

This definition highlights two important types of knowledge — explicit knowledge and tacit knowledge (see also Nonaka & Takeuchi, 1995).

Tacit knowledge refers to that knowledge which is embedded in individual experience, such as perspective and inferential knowledge. Tacit knowledge includes insights, hunches, intuitions, and skills that are highly personal and hard to formalize, making them difficult to communicate or share with others. Tacit knowledge is also deeply rooted in an individual’s commitment to a specific context as a craft or profession, a particular technology or product market, or the activities of a workgroup or team. In other words, tacit knowledge is deeply ingrained into the context, i.e., the owner’s view and imagination of the world, and into his/her experience, which is previously acquired knowledge.

Explicit knowledge is knowledge that has been articulated in formal language and which can be easily transmitted among individuals. It can be expressed in scientific formulae, codified procedures, or a variety of other forms. It consists of three components: a language, information, and a carrier. The language is used to express and code knowledge. Information is coded externalized knowledge. It is potential knowledge, which is realized when information is combined with context and experience of humans to form new tacit knowledge. The carrier is capable of incorporating coded knowledge and storing, preserving, and transporting knowledge through space and time independent of its human creators.

Both explicit knowledge and tacit knowledge are important for the organization. Both must be recognized as providing value to the organization. It is through the conversion of tacit to explicit knowledge and explicit to tacit knowledge in the organization that creativity and innovation are released and the potential for value creation arises. The goal, then, is to leverage both explicit knowledge and tacit knowledge and to reduce the size of the organizational knowledge gaps.

Knowledge Networking

A common thread running through many knowledge management initiatives is the challenge of developing and supporting new network-based communities, through which companies can improve internal collaboration and work more closely with partners and customers. Networks of people and networked organizations are emerging because the classic hierarchy of the bureaucratic model is slow to respond to the recent changes in the business environment. In the network, activities still need to be coordinated and integrated, but this integration relies on knowledge and relationships and a clear common sense of purpose. This has led to ideas about “work as a network of conversations” and the “hypertext organization” (see Nonaka & Takeuchi, 1995). Networks may take various organizational forms, ranging from communities of practice between individuals with similar experiences and/or purposes to supply chains of companies that exchange knowledge within their industry.

Knowledge networking levels correspond to what Nonaka calls the “ontological dimension” in his model of organizations as knowledge-creating mechanisms (see Nonaka, 1994). This ontological dimension refers to the social interactions, which begin at the individual level and then let knowledge expand and grow up by communication between organizational boundaries.

According to Nonaka and Ray (1993), if new knowledge is relevant to the needs of the organization, it is likely to permeate through groups and divisions and thereby extend the community of interaction dealing with that knowledge. New knowledge that has a potential to support more advantageous ways of doing things is likely to be retained as a subject for further debate within the network and may also lead to an extension of the network. For example, what eventually proves to be a successful product might emanate from an R&D department and gradually acquire a greater circle of interested parties within the organization as the dimensions of its potential impact become more clear. As news of the emerging product travels beyond the organization, the circle will grow still wider, embracing competitors, customers, firms dealing with complementary technologies, and so on. Thus the network will go beyond the original “hard core” of

knowledge creators to include those that are in some way affected by the exploitation of that knowledge.

However, there is no reason to suppose that there will be a linear sequence of expansion — starting from the individual, progressing to the group, and subsequently to the organization and beyond. The knowledge network could **span** departmental and organizational boundaries from the outset. Possible members of this community, such as suppliers, customers, and competitors, might all enter the knowledge networks at any time.

Knowledge networks are relationships among entities (individuals, teams, organizations) working on a common concern, and they embed dynamism for collective and systematic knowledge-asset creation and sharing. The structure of a knowledge network implies principles of coordination that not only enhance the individual capabilities of member entities, but themselves lead to capabilities that are not isolated to the network's members. Cooperation can also engender capabilities in the relationship itself, such that the members develop principles of coordination that improve their joint performance. Or they might involve more complex rules governing the process by which innovations are collectively produced and shared. In this sense, the network is itself knowledge, not in the sense of providing access to distributed information and capabilities, but in representing a form of coordination guided by enduring principles of organization.

Knowledge networks have five critical characteristics that differentiate them from other similar organizational structures and mainly from communities of practice (see, e.g., Wenger, 1998; Wenger & Snyder, 2000). These characteristics are the following: knowledge networks are responsible for creating, sharing, protecting, and cultivating common knowledge assets; knowledge networks are working networks and they are purpose driven; knowledge networks require organizational commitment beyond the commitment of their participating members; knowledge networks are built on expertise, not just interest — or common practice — alone; and knowledge networks aim at the development and strengthening of the learning capacity of all members.

Mentzas et al. (2002) distinguish between four levels of knowledge networking: individual, team, organization, and interorganization. The individual level refers to the capabilities, experience, competencies, and personal development issues treated at the individual level of the knowledge worker. The team and organizational levels include the internal company networks, i.e., the informal, self-organizing or the formal networks of people involved in related activities (e.g., project teams) that are built within an organization. The level of interorganizational networks refers to inter-enterprise relationships, value networks where each focuses on core competencies, as well as on the accessibility to external, developed capabilities. Hence networks with customers, competitors, subcon-

tractors, partners, etc. are included in this level. It is this fourth level of interorganizational knowledge networks and their impact on and implications for collaborative commerce that is the focus of our analysis in the following sections.

Knowledge and Knowledge Networks in Collaborative Commerce

Collaborative commerce is the use of online business-to-business exchange to facilitate the flow of business processes in addition to transactions (Gartner Group, 1999; Raisch, 2001). Business partners can exchange information such as inventory data by using a Web server as an intermediary. Furthermore, companies are seeking to exchange proprietary data, jointly manage projects, and cooperate on the design of new products. Collaborative commerce may also speed up cycle time for interaction between trading partners. Collaborative commerce requires that data such as product pricing, inventory, and financial information be shared among business partners.

When business collaboration moves beyond basic interaction to mission-critical collaboration, the question of public versus private exchange becomes an issue. Many of the capabilities and services required to drive significant value have been difficult to implement in a public environment. Public exchanges have struggled with a number of issues, including (Ferreira, Schlumpf, & Prokopets, 2002):

- the massive scope of true transformation of an entire industry's value chain
- integration of multiple technologies
- addressing member concerns around security and privacy
- enrolling and integrating member company trading partners
- convincing industry leaders to use standard capabilities and relinquish current advantage

The complex capabilities that proved difficult to enable in a public exchange environment are now being implemented with compelling results through private collaborative commerce networks. Unlike their public counterparts, private network capabilities can be tailored specifically to companies' unique value-chain needs and opportunities, can be built rapidly, and can allow companies to retain uniqueness and competitive advantage in collaborative commerce. Com-

panies can build and scale private networks covering a narrow scope of one process or covering a broad scope of multiple processes. Companies can also control and scale integration of trading partners — linking only the largest key trading partners or integrating hundreds or thousands. Companies building private networks can also sequence the build-out of capabilities to provide scalable return on investment at short intervals.

The recent take-up of private networks has allowed companies to share knowledge more effectively because they offer:

- (a) the required deep collaboration between buyer and seller;
- (b) speed and flexibility required for timely provision of critical, sensitive knowledge products;
- (c) privacy and control needed to create trusted relationships; and
- (d) quality of service that is a prerequisite for customer satisfaction.

The positioning of knowledge assets center stage in private networks is in line with the recent trend in strategic management that positions knowledge as the primary resource (Drucker, 1994), which is the primary assumption in the knowledge-based view of the firm (Eisenhardt & Santos, 2001). The specific knowledge base, the ability to make use of the available knowledge, determines the competitiveness of organizations in the emerging knowledge society (Franke, 2000). Such theories are unraveling traditional accounting procedures that can not account for new factors of production such as knowledge capital, intellectual capital, and intangible assets (Malhotra, 2000). A detailed account of these concepts is available in Stewart (1997).

Knowledge assets are different from other firm resources; see, e.g., Day and Wendler (1998) and Glazer (1991). They are not easily divisible or appropriable. This means that the same information and knowledge can be used by different economic entities at the same time. Moreover, knowledge assets are not inherently scarce (although they are often time-sensitive).

Knowledge assets are essentially regenerative. This means that new relevant knowledge may emerge from a knowledge-intensive business process as additional output besides products and services. They may not exhibit decreasing returns to use but will often increase in value the more they are used. This characteristic is of crucial importance for senior management; see, e.g., den Hartigh and Langerak (2001). Most assets are subject to diminishing returns, but not knowledge. The bulk of the fixed cost in knowledge products usually lies in creation rather than in manufacturing or distribution. Once knowledge has been created, the initial development cost can be spread across rising volumes.

Network effects can emerge as knowledge assets are used by more and more people. These knowledge users can simultaneously benefit from knowledge and increase its value as they add to, adapt, and enrich the knowledge base. In traditional industrial economics, assets decline in value as more people use them. By contrast, knowledge assets can grow in value, as they become a standard on which others can build.

A more detailed analysis of the factors that have an impact on the value of knowledge can be found in Apostolou et al. (2002).

A Typology of Knowledge Networks

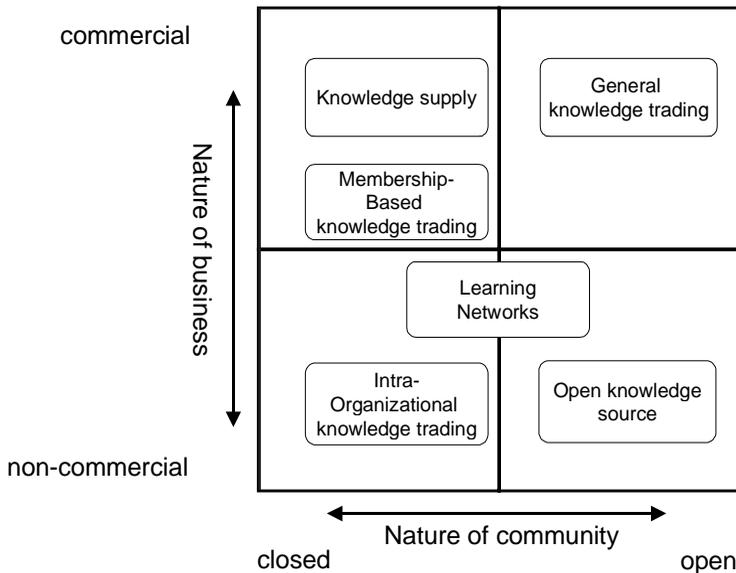
Knowledge flows between organizational units, such as individuals, teams, companies, or other types of organizations. These kinds of communities can be restricted to actors with specific access rights or can be open to everybody. Knowledge networks can be subdivided into those that are open to everybody or restricted to actors with certain rights. Typically these rights are defined by access rights, such as a membership identification, which might be gained by expertise, religious belief, or political conviction. On the other side it is also required that an actor complies with the obligations that are defined by the community for a particular role taken by the actor. From a strategic viewpoint we distinguish knowledge networks by the nature of the community in terms of access rights, whether it is a closed or an open community.

Because knowledge is a scarce resource, it has an intrinsic value that can be assessed by economical terms. In altruistic communities the value is the property of the whole organization, whereas in other communities knowledge is exchanged on individual or group level. In these cases the return for providing knowledge is valued by financial, e.g., money or stocks, or communicational, nonfinancial equivalents, e.g., reputation or decorations. This dimension of knowledge networks is represented by the “nature of business.”

Our empirical research on knowledge networks and knowledge trading marketplaces shows that six basic types can be classified. Basic types can be merged to hybrid types. For instance, parts of a knowledge network might be open to the general public and others are restricted to members, e.g., NetAcademy (www.netacademy.org).

In the following section, six such knowledge networks types (or generalizations) are described in more detail.

Figure 1. Classification of Knowledge Networks in the Extended Enterprise Context



Open Knowledge Source

An open knowledge source is a noncommercial and open knowledge network. Knowledge assets can be readily available or be created by its members by answering to a knowledge need. Access rights are granted to everybody, and in general actors do not have to comply with specific obligations. Typically there are services, which allow for searching and browsing based on some categorization or ontology. Benefits for the members include unrestricted access; knowledge users will benefit from a potentially high number of information objects and expertise, which are readily available. This attracts new participants and offers the opportunity of fast community building. Experts providing their knowledge will usually be motivated by expected reciprocity, a gain in reputation, or even by altruism. The network operator can earn revenues by means of advertising or co-branding the Web site. Another opportunity is to offer added value services. Examples for open knowledge sources are ICQ and Google. Languages used in open knowledge source communities and the information richness of accessible information objects are in general quite heterogeneous. The value of these types of communities is derived from the free and anonymous access.

Intra-Organizational Knowledge Networks

Intra-organizational knowledge networks are closed and noncommercial communities. In organizations people search for knowledge because they expect it to help them with their work. Within organizations cash is usually not involved in these transactions, but that should not disguise the fact that a market price system exists and “payment” is made or assumed. The intra-organizational knowledge market, like any other, is a system in which participants exchange a scarce unit for present or future value. Basically it’s reciprocity. “I’ll help you because you’ll help me in the future.” Some altruism exists, but generally the market principles are pretty strong (Davenport & Prusak, 1998).

As an organization indirectly benefits the knowledge sharing platform if its participants do, it can spend resources for running the market and improve its quality and efficiency by adding knowledge reviewers and brokers.

Due to the noncommercial nature of the community, sources of revenue are based on outsourcing gains of technical operations (outsourcing concept) and community operations and quality management (outsourcing concept), which are paid by the organization. Simplistic forms of intra-organizational knowledge trading communities are intranets like ShareNet at Siemens. A more elaborated form of closed, noncommercial knowledge network is the Open Source initiative such as Apache Software Foundation. These kinds of knowledge networks consist of hierarchical organizational structures with clearly defined rights and obligations for each role and a highly specialized language. Financial benefits are generated outside the knowledge network but in association to the network.

Membership-Based Knowledge Networks

Membership-based knowledge trading communities are closed communities with a varying degree of commercialization. Information objects can be either covered by the membership fee or can be charged additionally. In an English club, newspapers are covered by the club fee, whereas a subscriber of the newspaper *Frankfurter Allgemeine Zeitung* (FAZ) has to pay for the archive.

Revenues are gained by a membership fee per period. Pay per use, pay per user, pay per information object, and pay per period are possible models. An academic journal like *Electronic Markets Journal* (www.electronicmarkets.org) is a traditional means of subscription-based knowledge distribution. Organizations with high expertise in specific domains offer membership-based access of their expertise to client organizations; examples include research and technology organizations like the Welding Institute or business and market research orga-

nizations such as Nielsen. One of the key challenges for traditional membership-based organizations is to charge their subscribers for certain kinds of information objects. The well-accepted rule that everything is for free needs to be overcome. In cases that the additional value does not exist and/or it is not communicated in a proper way to the community, the approach to move a membership-based community from a noncommercial to a commercial either fails or even threatens the whole business model.

Knowledge Supply

Similar to modular suppliers of goods, knowledge can be supplied by standardized channels. This knowledge network is implicitly well-known by companies that established a strong relationship to a specific consultancy. Access rights, obligations, and the language between the company and the consultancy are well-established, which supports an efficient exchange of knowledge.

A knowledge supply has fewer actors in the form of suppliers and buyers than an open market, but they have a closer mutual relation. There are some reasons why a closed network like this may be a better means of supplier-buyer interaction than open markets:

- It may be too difficult to select the best supplier in cases of an overabundance of suppliers, and networks thus serve to reduce search costs.
- It may be difficult to detect who may be interested in the knowledge products outside the lines of known people.
- The intangible nature of many knowledge products complicates with price formation and ownership.
- Stable knowledge networks as provided by knowledge supply channels establish trusted relationships, which also encompass a mutual understanding of the domain and expertise.

Knowledge supplies can be found in areas with formalized and codified languages (type A), such as engineering, computer science, and business audits, but also in areas with informal languages such as traditional consulting (type B).

In type A we find again well-established, specialized languages, which are used to exchange complex knowledge. In particular engineering has developed formal codes that are the basis for describing and solving problems. These codes are learned over years at universities. Engineering associations are important links

so that also people on the job keep inside the moving scope of the language. Examples for type A knowledge suppliers are the Welding Institute for engineering, e-institute for electronics, Apache Software Foundation for computer science, and Caliso Consulting for ISO9000.

Consulting companies tried over years to establish a common language that gives enough freedom for differentiation but gives enough logical structure so that companies can unleash transferred knowledge. Nevertheless consulting is still a people-oriented knowledge network so that knowledge supplies are attached to single experts, who transfer their trustworthiness to additionally supplied consultants. In more formalized areas of economics, business consulting can provide knowledge supplies in the sense of type A. Examples are know-how on procedures for the evaluation of mergers and acquisitions and other controlling areas.

Direct sources of revenue for knowledge supply networks are, besides others, pay per use, pay per user, pay per information object, pay per period, technical operations (outsourcing concept), and community operations and quality management (outsourcing concept). If knowledge will be used in a problem-solving context, revenues could also be charged on a success basis. For instance, this could be used in product design and developmental scenarios.

Knowledge suppliers can either operate independently or in conjunction with others. In the latter case, marketplace functions are required. Additionally they can integrate, syndicate, or meliorate knowledge services of suppliers, as it is known from the newspaper industry.¹

The demand for knowledge suppliers in sense of type A is rising as the market for expertise gets more transparent. This will nurture fractal and distributed organizational structures that temporarily in-source high-level expertise, as known from the pharmaceutical industries for product development. This requires a industrialization of knowledge-based organizations.

General Knowledge Trading

The general knowledge trading network is an open and commercial marketplace. The idea of an open marketplace with many different buyers and suppliers implies that price and volume are the most important determiners of supply and demand (Wijnhoven, 2001), which is the case for commodity goods. Applied to knowledge markets this may happen when many suppliers offer similar products. Two different kinds of knowledge commodities require diversity in the markets' services:

- *Homogeneous knowledge commodities.* These commodities consist of clearly identifiable (highly codified) knowledge products, like books. These knowledge commodities consist of information objects, supplied one at a time.
- *Data packs.* In comparison to homogeneous commodities, these data packs are more flexible in shape and have larger opportunities of meeting specific information needs because much of the information is unbundled. The buyer may be given the opportunity of specifying his information need and as such create his own information bundles. Examples of this kind are market information services and news agency services, which enable their customers to buy a selection of information objects.
- *Procedural knowledge packs.* Problem solving can be seen as a step-by-step procedure that allows one to ensure a desired goal situation. In formalized areas, these procedures can be packaged and sold. Examples are certain types of due diligence methods or credit risk procedures. They can be applied by buyers if they are able to understand the logical structure, which contains the necessary roles, required expertise, and step-by-step behavior of the procedure. Examples are the best practice guides provided by TWI.²

The experts and knowledge publisher benefit from an additional outlet and, by means of this, an increased demand for their knowledge products, which is the basis of their revenues. Examples of general knowledge trading networks are: www.knexa.com and www.hotdispatch.com.

Learning Networks

The term learning network does not refer to networks where learning simply happens, as is the case with communities of practice — groups of people who share a concern, a set of problems, and who deepen their knowledge and learn by spontaneously interacting on an ongoing basis (Wenger, 1998). On the contrary, learning networks are interorganizational networks formally established to increase the participants' knowledge and innovative capability. Learning networks are formally established and defined; have a structure for operation with boundaries defining participation; have a primary learning target; have formally developed processes that can be mapped on the learning cycle; and have a practical learning outcome that can be measured.

Examples of learning networks include professional associations (Institute of Mechanical Engineers, UK), sector-based associations of firms with common

interests in the development of the sector (Automotive Cluster of Styria, Austria), industry research and technology networks, supply-chain initiatives (particular firms supplying to a major customer — e.g., Toyota — Kyokoryku, Japan), region-based networks (3rd Italy), and government-promoted networks (London Innovation and Technology Counselor's network, UK).

Learning networks exploit the widely used approach termed “action learning”: the active participation, challenge, and support of groups of employees facing similar problems. The whole idea of action learning is based on the combination of personal example (the action dimension) with the notion of learning community. This concept stresses the value of experiential learning and the benefits that can come from gaining different forms of support from others in moving around the learning cycle. Self-learning within a group has much to offer to organizational learning and competitive advantage; the experience of regional clusters of small firms provides one important piece of evidence in support of this. It has been increasingly recognized that organizational knowledge results from complex and multifaceted interactions among different individuals.

Enabling Technologies for Knowledge Networks

Technologies used as media for communities of knowledge networks need to capture social, semantic, organizational, and process-oriented structures. Knowledge workers, such as in open source communities, meet for specific beliefs, intentions, and desires. For instance, tools are required to support open and democratic communication between all members of the group. On the semantic level a community defines meanings, which are codified in signs and symbols. The technology should provide means for learning, exploring, and applying the semantics on the basis of services. For instance, mail is based on the semantics of traditional mail. Therefore a user needs services for sending and receiving e-mails as well as an e-mail box. On the organizational level technologies for knowledge networks need to provide sufficient means for creating roles. For instance, a classroom requires the roles of a teacher and a student. Knowledge media such as knowledge networks demand clear role sets so that every participant understands his/her role and the role of others. Also, in this case, open source communities provide excellent cases for organizational structures for knowledge networks. Finally, the technology needs to provide means for implementing process on top of services. The requirement for synchronous communication in collaboration situations can be implemented on top of instant messaging, IRC, or even Wiki. The implementation of the process will differ, but

the requirement on social, organizational, and semantic levels to be fulfilled stays constant.

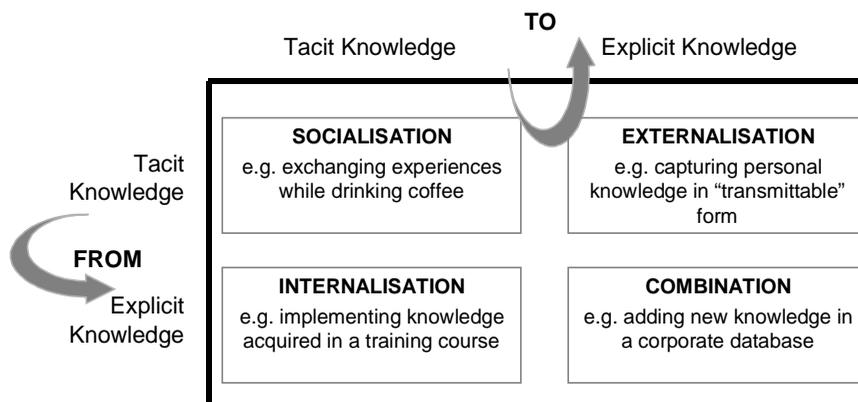
Furthermore technologies supporting collaborative knowledge networks must operate efficiently in open environments with practically no geographical, temporal, cultural, and technical limits. This type of environment is characterized by the fact that participants are autonomous, i.e., they can come and go act independently, and are self-contained. For a specific purpose they may be willing to participate in loosely coupled communities, taking some role and responsibility and/or providing some services. In such communities, they may negotiate and fix some agreements, perform some tasks, provide and/or access some information, and access or offer some resources, while others are restricted to their own use. Consequently technologies used in such environments must support loose coupling, autonomy, and flexibility on the one hand and agreement making, trust, and security on the other hand (Tschammer, 2001).

Nonaka and Takeuchi (1991, 1995) in their reference study about knowledge creation in the Japanese industry are distinguishing two types of knowledge flowing in any kind of knowledge transaction: explicit and tacit. *Explicit knowledge* is formal and systematic and, thus, easy to communicate and share; it is knowledge that is transmittable in a formal language and can be stored in databases, libraries, etc. *Tacit knowledge* is personal knowledge that is hard to transmit; it consists of mental models, beliefs, and perspectives that can not be easily articulated and shared.

Accordingly, four types of interactions (or modes of knowledge conversion) can occur during knowledge transactions: from tacit to tacit (socialization), from explicit to explicit (combination), from tacit to explicit (articulation), and from explicit to tacit (internalization) (see also *Figure 2*). It is important to notice that although the modes of knowledge conversion were initially proposed by Nonaka and Takeuchi as the basic patterns for knowledge creation and management within organizations, they can be equally applied to model and understand knowledge transactions in the extended enterprise or at the supply-chain level. Understanding the flow of tacit knowledge and how tacit knowledge can be transferred or converted to explicit knowledge is of immense importance for the design of appropriate IT supporting tools for collaborative knowledge networks.

In order to understand how information technology can support knowledge transactions, it is convenient to focus on each one of the four modes of knowledge conversion. A classification of existing information technology tools according to the four modes of knowledge conversion is presented below (see also *Table 1*).

Figure 2. Modes of Knowledge Conversion



Source: Nonaka and Takeuchi (1991, 1995)

Table 1. ICT Support and Examples of Tools for Each Mode of Knowledge Conversion

Mode	Support required for	Examples of tools
Socialization	informal communication on-line discussions during work question raising information discovery	e-mail, discussion lists, collaborative hypermedia, multimedia conferencing, brainstorming applications
Internalization	search for methods & lessons- learned process documentation knowledge sharing knowledge interpretation	lessons-learned databases, information retrieval, process history tracking, case-base retrieval, data warehouses
Externalization	concept mapping tacit knowledge: categorization / representation organizational memory creation personalized pathways	semantic annotations, ontologies, publishing tools, push technologies agent technologies issue-based argumentation
Combination	knowledge sharing decision co-ordination	computer-mediated communication, searching and filtering, document management, workflow systems, group decision support systems

Knowledge Socialization

Knowledge socialization generates new tacit knowledge by sharing and exchanging know-how and past experiences. Socialization can receive direct support from information technologies that make users communicate without imposing any particular structure on their interaction. A more structured approach, like workflow management, can also powerfully support knowledge management by enabling the interaction between communities associated with different functional domains of the organization.

Collaborative knowledge management software must support the creation of communities or networks within the corporate network and beyond. This requires an environment that supports knowledge sharing and knowledge capture. A collaborative environment must offer the flexibility to support a range of projects and applications, as well as a robust framework that is integrated with the corporate infrastructure for communication and information management.

The functions that a collaborative environment should offer include:

- *Synchronous communication.* Synchronous messaging allows users to set up a conversation in real time over the network. Associated services include the ability to identify colleagues who are available online. In the future, net video and net telephony will be integrated with collaboration environments, as an alternative means of linking users in real time over the network.
- *Net spaces.* Tools such as Microsoft's NetMeeting and Lotus's Sametime are enabling users to work together in real time over a network. Users can work together on documents and hold conferencing and whiteboarding sessions via an intranet or the Internet. Such services need to be supported by appropriate security and management functions (for example, integrated versioning and locking of documents).
- *E-mail and beyond.* Functions such as synchronous communication and the provision of net spaces take the basic tools provided by e-mail to a new level. The other advance concerning e-mail will be to integrate it with the knowledge repository in a much more flexible and transparent way. Threaded discussion groups should be easy to define and administer. E-mail and discussion groups also need to be integrated with the repository, so that discussion, annotations, and comments are available as part of the network memory.
- *The ability to form communities and linking users to knowledge.* This depends on a comprehensive directory of resources. Improvement in the integration of directory services, based on the take-up of LDAP and

improved automation of expert profiling and discovery, will make it easier to find the right person across the network.

Knowledge Internalization

Knowledge internalization maps explicit knowledge into internal knowledge. Internalization happens when individuals exposed to other people's knowledge make it their own. People internalize knowledge by doing, but also by looking at what other people have done in a similar context and by example. Information technology tools can record explicit knowledge and make it available to potential users and enable them re-experience what other people have done in similar situations, help them familiarize themselves with analogous situations, etc. Indicative information technologies supporting this mode are data warehousing, data mining, computer-based training (CBT), etc.

Knowledge Externalization

Externalization involves structuring knowledge and making it available to other users. This is a crucial step in the knowledge life cycle that leads to the creation of the network *organizational memory*. Knowledge externalization has been traditionally supported by a number of artificial-intelligence-based technologies, such as agent-based technologies, and semantic enrichment of information mainly through the use of ontologies.

Ontologies have been recently introduced (Davies, Fensel, & Van Harmelen, 2003) in information technology as the working model of entities and interactions in some particular domain of knowledge or practices, such as welding of materials. In this usage, an ontology is a set of concepts — such as things, events, and relations — that are specified in some way (such as specific natural language) in order to create an agreed-upon vocabulary for exchanging information. Loosely coupled, autonomous entities, which have to collaborate in an open environment, need ontologies to define a common language and a common set of terms for the environment wherein they have to collaborate.

In order to cope with the great complexity of the knowledge exchanged in the context of such networks, a knowledge-rich formalization of knowledge assets and the domain of application seems an appropriate backbone of the knowledge network system. This approach is becoming increasingly important for information retrieval tasks in digital libraries or Internet information search (see McGuinness, 1999).

Another important technology that is exploited mainly to support knowledge externalization is software agents. Software agents are autonomous software

entities that automate a set of tasks delegated to them either by people or other software processes. An agent has its own state, behavior, thread of control, and an ability to interact and communicate with other entities — including people, other agents, and legacy systems — in an autonomous, intelligent, and proactive way. The agent paradigm is different to the traditional client-server approach. Agents can interact on a peer-to-peer level and mediate, collaborate, and cooperate in order to achieve their goals and objectives (Tschammer, 2001).

Knowledge Combination (or Systematization)

Knowledge combination generates new knowledge by combining preexisting explicit knowledge and bringing it together to produce new insight. Systems that provide access to distributed explicit knowledge (such as distributed databases and workflow applications) are typical supporting tools for knowledge combination.

Peer-to-peer is a communications model in which each party has the same capabilities, and either party can initiate a communication session. In recent usage, peer-to-peer has come to describe applications in which users can use the Internet to exchange files³ with each other directly or through a mediating server. On the Internet, peer-to-peer (referred to as P2P) is a type of transient Internet network that allows a group of computer users with the same networking program to connect with each other and directly access files from one another's hard drives. Napster and Gnutella are examples of this kind of peer-to-peer software. Virtual communities are already exploring the advantages of using P2P as a way for sharing information and knowledge resources without the expense involved in maintaining a centralized server and as a way for businesses to exchange information with each other directly (see, for instance, the SWAP project, swap.semanticweb.org).

Knowledge process modeling is the task of describing all relevant aspects of a knowledge process. Modeling of interorganizational knowledge processes — as required in collaborative e-commerce — must cover aspects that are specific to processes that cross enterprise boundaries, including business rules, security roles, distributed transactions, and exception handling.

On the back end, technology integration standards such as XML Schema, SOAP, and J2EE enable the convergence of legacy infrastructures toward process-oriented enterprise computing. On the front end, emerging protocols such as ebXML, RosettaNet, and BizTalk support the process-level collaboration within a knowledge network.

In the following two sections we examine two specific toolkits for interorganizational knowledge networks that were built by adopting some of the previously mentioned technologies.

WIT: A Case of Knowledge Sharing at the Supply Chain Level

Introduction

Although firms work hard to invent and improve processes themselves, they also at times want to share process or product knowledge among firms. For example, knowledge sharing within a supply chain has become a common practice because it promises to enhance the competitive advantage of the supply chain as a whole (Bell, Giordano, & Putz, 2002). It is sometimes the case that companies even require that their suppliers implement interorganizational information systems to improve organizational coordination and product quality (Holland, 1995). In other cases it is the introduction of such systems that is triggering the formation of new organizational entities to resume the role of the information broker (Sakkas, Malkewitz, & Apostolou, 1999) and in effect reshape the tradition supply chain.

The WIT toolkit was developed as an Internet platform to support the collaborative enterprise paradigm in the wood/furniture supply chain, focusing primarily in the field of design, sales, and marketing. This toolkit, addressing the main functions required within the targeted supply chain, operates partly locally on the end user's computer and partly in collaboration with remote entities (WIT-servers). The architecture of the client as well as the server applications allows for the possible modification of the existing tools or the extension of the basic tool set by integrating other functions. This approach, along with the careful design of the infrastructure, allows WIT to be adopted and used in the domain of other supply chains, outside the wood industry.

WIT Architecture and Functionality

Technically speaking, the WIT infrastructure is based on a three-layer service architecture, where the main elements are: (1) WIT-N layer, its main purpose being to provide directory services, which will help clients navigate themselves to the correct sites, where meaningful (to their purpose) product information might be hosted; (2) WIT-server layer, hosting three kinds of services (and the respective data, naturally): user administration, product data delivery, and a "point of contact" service (collaboration brokering); and (3) WIT-client layer, consisting of an applet that provides an integrated user interface to the WIT functionality. (The end user may search for furniture products, thereby building

Table 2. WIT Applications

Application	Description
WIT.Project	As the user (architect) usually organizes his work by projects, it is natural to follow this strategy within the client software. The so-called Project Manager part of the client software lets the user define what kind of space has to be furnished, how it is divided into rooms, who is the end-customer, how much money might be spent on furnishing, and so on. The definition of the project provides guidelines for the remainder of the functions.
WIT.Query	The user must be able to find furniture that best matches the project requirements, which is a core functionality also from the vendors viewpoint. In the Query Tool, the user specifies values for a number of attributes, for which WIT-servers can search in their databases. Results are displayed on the same screen, so that interactive refinement of query attributes is possible.
WIT.Space Planner	To give a best possible impression of how a certain combination of furniture would look like in a room, a 3D composition tool is included in the client software. The goal of the SPACE PLANNER (Figure 3) is visualization of such a composed design, rather than precise planning for construction. The emphasis here lays on good graphics performance and ease-of-use.
WIT.Quotation and WIT.Order	Both quotations and orders are managed by a tool called the Quotation Builder, which helps the user in preparing requests for quotations and in dispatching orders. It is possible for an end-user to go through an interactive cycle where a series of parameters may be settled before placing an order.
WIT.Collaboration	The user is enabled to get into personal contact with service people on the server side using collaboration mechanisms, such as video-conference. These may be sales people or technical support staff, depending on the kind of questions that may arise. This capability provides companies with a more efficient and competitive customer support strategy. The collaboration tool is flexible enough to also be used as a training tool, e.g. for introducing new products and best practice cases. With collaboration, it is possible for the company to have geographically dispersed expertise, thus making better use of its human resources.
WIT.Server Query	This part of the client system sends out calls to the directory service provided by the WIT-N server. If a user is unsure, which WIT-server to contact, he performs a kind of meta-search and gets back a list of WIT-servers that provide the kind of products the user is looking for.

up his own customized product catalogue, build interior designs with the chosen products, negotiate prices or other details, and finally place orders.) The applications of the WIT toolkit are presented in *Table 2*.

A graphical representation of the WIT functions is shown in *Figure 4*. For a more detailed presentation of the WIT architecture (Sakkas et al., 1999).

Figure 3. WIT Space Planner Tool

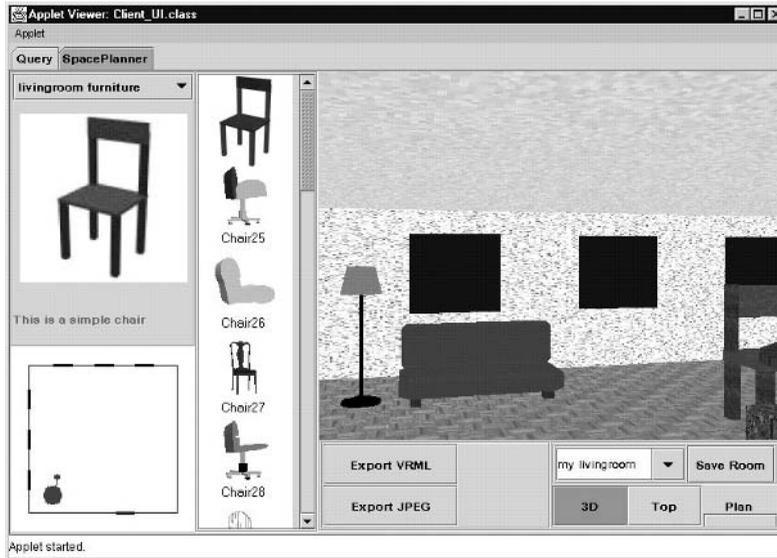
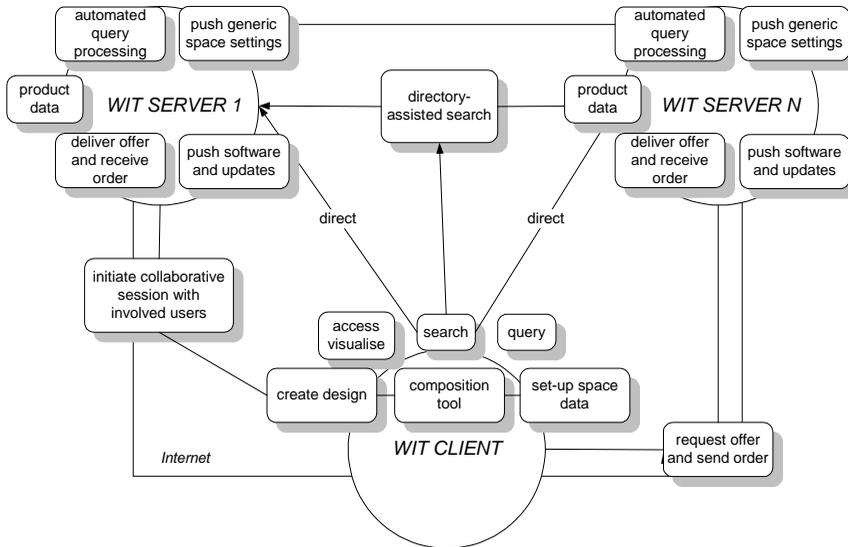


Figure 4. WIT Functional Architecture



How WIT Supports Knowledge Transactions

In this section we discuss how the different tools of the WIT toolkit provide support for enacting the four types of knowledge transactions.

Knowledge Socialization

WIT uses a structured approach, supporting a virtual work environment for design and training between communities associated with different functional domains within the same or between different organizations. *WIT.Collaboration* supports the creation of virtual work environments to discuss and agree on different aspects of furniture design, construction, and application. A WIT client can interact with other WIT clients and server(s) in order to optimize the exchange of ideas and information between architects, decorators, and customers. In summary, a collaboration session consists of audio/video conferencing, whiteboard functionality, and application sharing.

Knowledge Internalization

Company-specific knowledge on products and services, such as product information, best practices, and training material in multimedia formats, can be codified, stored, and made available through *WIT.Query*. This tool concerns itself with providing access to the value-supply-chain knowledge assets. The WIT searching mechanism is characterized by the ability to post requests to the whole network or to parts of the network. The first type resembles the well-known Web engine type of searching, while the second provides a map to the product and other information residing in the WIT servers. The user posts can traverse the whole WIT network and select appropriate servers based on domain or product characteristics, such as country, product range, price range, etc.

Clustering of results based on the metadata categories defined in the product data model enables the user to quickly drill down to or mine the most relevant knowledge assets.

Knowledge Externalization

WIT provides the *3Dcatalogue* application to support this mode. The 3-D electronic catalogue presents for each WIT server the wood products organized by product lines, furnished model rooms, price lists, availability indication, etc. For each product, the catalogue presents information such as parts structure,

geometry-allowed adjustments, materials, colors, textures, dimensions, finishing, assembly details, and maintenance details. The 3-D electronic catalogue extends with advantage the 2-D paper catalogue, of great use in the specific sector. The electronic version can be kept updated in product line, availability, and price list without the fixed costs associated with paper publications. This is the most powerful facility to support the design decisions. The creation of a virtual space, the ability to visualize 3-D objects and spaces, as well as the impact of different finishing, colors, textures, and lighting can expedite drastically the project concept decision. In addition *WIT.SpacePlanner* allows one to visualize 2-D spaces and 3-D models. The space planner is a composition tool that replaces the freehand sketch drawing by the architect to illustrate a solution and includes the legal, technical, and best practice constraints that are specific knowledge of the project designer. Additionally it allows one to populate the office space with different versions of furniture, converging to the full satisfaction of the client under the designer's guidance.

Knowledge Combination

WIT.Project provides a repository of information related to the client furnishing project decision process, the project negotiation process, the capturing of user requirements, and the project start-up. The decision to develop a new office project is a complex process with multiple drivers as well as constraints. It might be a decision taken inside a corporation who develops clear terms of reference or only develops the project idea in dialogue with the office design specialist. In both cases WIT can provide different room models exemplifying different styles and applications. WIT supports the project definition with a number of pre-defined **scripts** allowing users to define office space area, business organization characterization, type of business, business strategy, evolution plans, number of users, budget target, and project schedule.

Discussion

A significant benefit of the “knowledge supply chain” type of knowledge networks, such as the WIT one, is that they help increase the sector's “surface area,” or the number of points at which it has access to knowledge. Companies that participate in such networks are much more likely to stay in the knowledge flow than those that do not (media richness theory, TAM, ...). Such access is as important in continuously refreshing knowledge as it is in acquiring it in the first place.

The WIT infrastructure in particular leverages the existing business model of wood sector companies to move beyond the static, product-oriented environment of today into the community and conversation environment where knowledge provision is a key enabler factor. In this environment, a designer will visit the WIT virtual world to see and read about a new product of Company X, or she can search among the WIT servers for a product that fits her needs. She will then be able to discuss with other users (architects, designers, etc.) or with the manufacturer itself about product functions and best practices or see successful installations. In a way, WIT has the capabilities of fostering an organic community. Clearly, the technology is seen only as an enabler; it is the community members who will maintain the ties that bind them together. The role of the technology — and of the broker providing and maintaining it — is to further facilitate the growth of that community by assuring that value chain members enjoy closer contact with each other and with the knowledge sources.

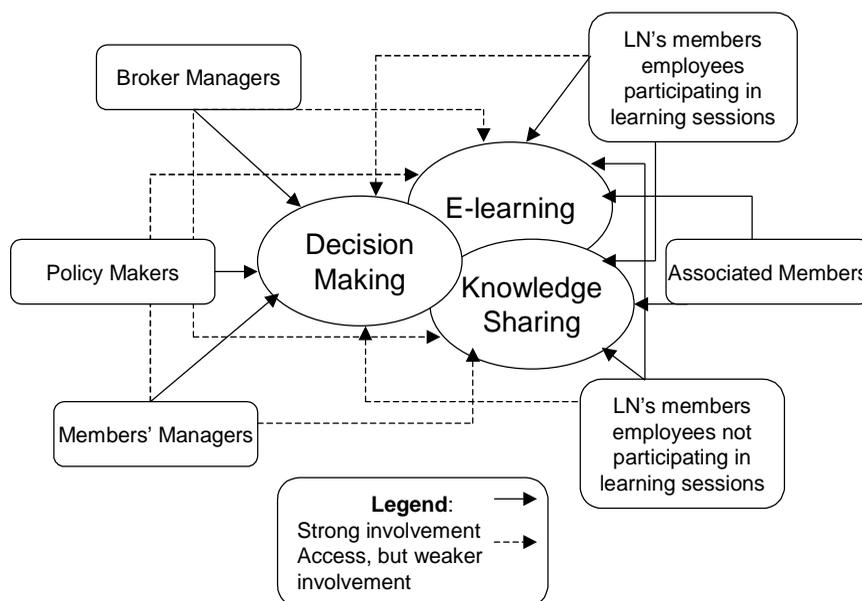
KNOWLaboration: A Case of Interorganizational Knowledge Sharing and Collaborative Learning

Introduction

The potential of knowledge networks (i.e., one of the six types of knowledge networks defined earlier) for the distribution of explicit knowledge (i.e., knowledge that is pinned down verbally in writing or electronically and can therefore be communicated and distributed) is undisputed. However, what is also required is an integrated approach that includes both explicit and tacit knowledge. Tacit knowledge can be conceptualized as processing a technical and a cognitive dimension (Seufert, von Krogh, & Bach, 1999). Whereas the technical dimension contains informal, personal abilities and skills, the cognitive dimension includes mental models influenced by beliefs, values, and convictions (Nonaka & Takeuchi, 1995). For this reason and in order to make effective use of knowledge, a network must be built up in which the knowledge and experience of employees are available (Seufert et al., 1999).

The KNOWLaboration toolkit was developed specifically with these objectives in mind: to provide an infrastructure based on the Internet to support the advancement of knowledge as well as the learning of the participating employees. It exploits the widely used approach termed “action learning”: the active

Figure 5. Main Functions and Roles of a Learning Network



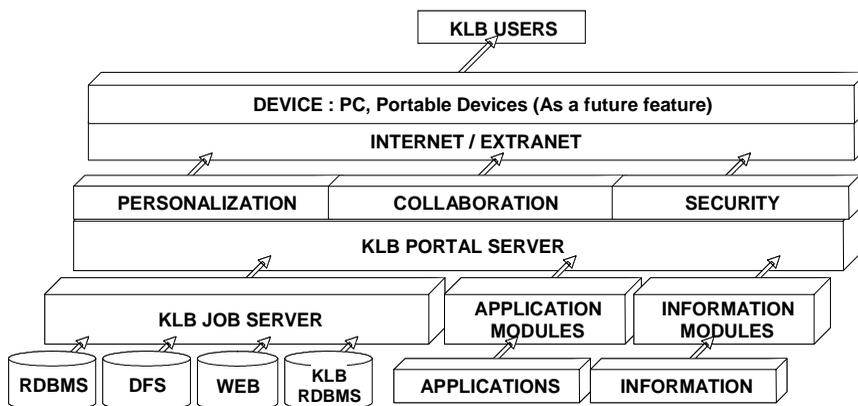
participation, challenge, and support of groups of employees facing similar problems (Pedler & Boydell, 1991).

KNOWLaboration Architecture and Functions

The KNOWLaboration toolkit is developed to support five⁴ main categories of users (Figure 5):

- The managers of the broker organization who coordinate or wish to coordinate the knowledge network.
- The managers of the collaborating organizations who have decision-making responsibilities within the network; the number of managers with such responsibilities varies from a few people representing all members to one representative from each collaborating organization.
- The employees who participate in actual learning and knowledge-sharing sessions of the network.
- The employees who do not participate in specific learning sessions of the network; usually members appoint specific persons to follow the learning

Figure 6. Architecture of the KNOWLaboration Toolkit



sessions of the network who, however, find it difficult to convey the learning content of the sessions to the rest of the organization.

- (e) The employees of associated members (if existing) who can also reap the fruits of learning that is taking place within the network if the network decides to allow access to the shared knowledge base; this is the case of members who pay reduced subscription and have limited participation and access to the network. Depending on the specific case, a learning network may allow access to unregistered Internet users.

Table 3. KNOWLaboration Subsystems

Subsystem	Description
1. Knowlaboration Portal Server	This is the core engine of the system. The Knowlaboration Portal Server provides Content Management facilities, Document Management facilities, a Personal File Manager, a Project Workspace, Search Facilities and a Reporting and for auditing the usage of the system.
2. Knowlaboration Job Server	Manages all the system's content by accessing different data sources. It also performs standard jobs in order to update the contents and the index that will be later used for searching the system.
3. Knowlaboration Security Engine	Manages all the system's security.
4. Collaboration Tools	These tools allow the collaboration of the users in several ways (synchronous / asynchronous) The Collaboration tools are: E-Mail, Forums, SMS messaging, Chat engine, Instant messaging, Video conferencing / Audio conferencing.
5. Personalization Engine	This engine allows the filtering of information to the user in such way that it meets personal criteria given by him/her. The personalization can extent to user groups (channels) or each user according to the level of IT knowledge each one carries.

Figure 7. KNOWLaboration Home Page

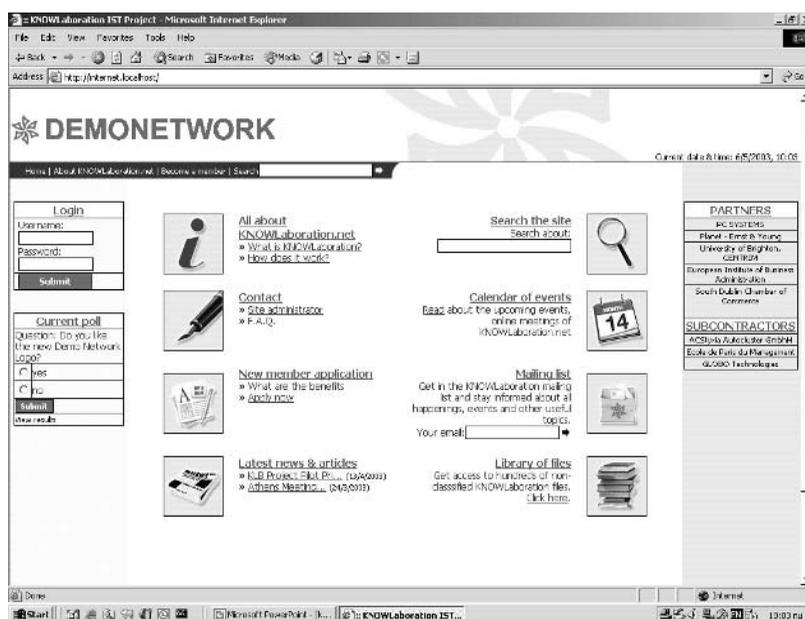


Figure 6 shows the several subsystems that constitute the KNOWLaboration toolkit, which are described in Table 3. Figure 8 presents the functions that the toolkit provides to the five categories of users.

How KNOWLaboration Supports Knowledge Transactions

Knowledge Socialization

Various collaborative tools (mail, forums, SMS messaging, chat engine, instant messaging, and videoconferencing/audio conferencing) support knowledge socialization. These tools allow the collaboration of the users in both synchronous and asynchronous modes. What is important to note though is the non-IT support that these types of networks provide to the participating members. Face-to-face collaboration is encouraged through the organization of physical meetings, factory visits, seminars, and workshops.

Figure 8. KNOWLaboration Functions Supporting the Five Categories of Users

BASIC APPLICATIONS FOR ALL USERS	USERS
<ul style="list-style-type: none"> •Portal Interface •Organization Structure •Network Time •Users On line •Notes •Search 	<ul style="list-style-type: none"> •News •User Profile •Instant Messaging •Personalization •Personal file Manager •Web mail •Participating employees •Non-participating employees •Associated members •Managers with decision making responsibilities •Broker
GROUP LEARNING ORIENTED APPLICATIONS	USERS
<ul style="list-style-type: none"> •Group Area •Forum •Chat •Web Calendar •Polls •Document Management •Contacts Management •Dissemination Tools •Voting Forums •News 	<ul style="list-style-type: none"> •Participating employees •Managers with decision making responsibilities
ADMINISTRATION APPLICATIONS	USERS
<ul style="list-style-type: none"> •Permission Management •Platform Management •Applications Management •Usage Reports •Mailing Lists 	<ul style="list-style-type: none"> •Broker

Knowledge Internalization

One of the most usual problems of learning networks is the restriction of the learning and knowledge gained during the formally organized, real-time, collaborative sessions of the network. If an individual member is unable to follow one session due to time or work restrictions, he/she has no way to access the missing part of his learning trajectory. To support this “knowledge internalization” process, the KNOWLaboration toolkit records these sessions (using various tools such as lessons-learned techniques, multimedia archives, etc.), which can enable collaborating members to minimize their losses from missing particular sessions. This way the KNOWLaboration toolkit can help the network to increase both the duration and the efficiency of the knowledge and learning. For instance, it supports (using structured, facilitated discussion forums) follow-up sessions that expand knowledge internalization in between the formally organized learning sessions.

concerns itself with sustaining the momentum of the community that has been set up and sustaining active knowledge sharing within the community. The IT tools should provide facilities to support the maintenance and growth of the network and member management facilities that will help user integration for the main activities of the network. Typical features of this kind include synchronization of calendars and synchronous events. Other useful facilities aiming at promoting and marketing the network to relevant stakeholders include invitations, minutes of recent events, and hot topics. (3) Facilities during the operation phase should monitor if the individual members can see benefits for themselves and their business.

The second recommendation refers to the integration of the system with existing business processes. Participation in a learning network usually competes with other priorities in the lives of members. It is crucial to make participation as easy and efficient as possible. ICT therefore should make participation easy by providing time and attention management through functions such as personalized knowledge/application portals, subscriptions, tours of new activity and archiving of interactions, and integration with work systems.

The third recommendation clarifies that the learning network system should address the issues of presence, visibility, and motivation (see also Wenger, McDermott, & Snyder, 2002; Wegner & Snyder, 2000). Personal identities are a crucial aspect of participation. Members bring their identities to the community, and their participation both develops and shapes their identities. IT can help with features such as member profiles, ranking and preferences, and presence awareness. A collaborative community such as a learning network has also a sense of communal identity that is primarily formed by cultivating “alive and real” relationships between the members. The use of personal profiles in the ICT system can reveal relationships and support private interactions and interpersonal and mentoring relationships.

Fourthly, a learning network should thrive to deliver value both to its members as well as to the stakeholders and the network as a whole. In the short term, members need to find immediate value in their participation. Preserving the time of experts within the network is, for instance, an important concern. The IT system should provide mechanisms for asking questions, lists of FAQs, databases of answers, intelligent access to experts, and brainstorming facilities. The value that the network delivers also has a long-term dimension. It derives from a sense of accumulation over time. In order to define “best practices,” the IT system should provide repositories for artefacts, taxonomies, search mechanisms, and learning agendas.

The value of belonging to a learning network derives not only from having access to peers, but also from having access to the leading edge in the broader world (Wenger et al., 2002). Therefore as a fifth recommendation, we stress the need

Knowledge Externalization

A very important barrier for increasing the efficiency of learning networks is related to the difficulty of the individual members who participate in the network to pass the gained (tacit) knowledge to the rest of the organization. The KNOWLaboration toolkit learning sessions' archive and recording facilities allow more people from the organizations to access the issues discussed during the learning sessions effectively, reducing significantly the diffusion barrier.

These facilities are useful also for members that join the network at a later time who otherwise could not benefit from previous learning that had taken place in the network, missing a valuable part of the learning trajectory. The training services provided by the toolkit support lately joined members, enabling them to cover part of the lost ground.

Knowledge Combination

Decision making in collaborative learning networks is critical for their success since decision making results from the specification of a variety of issues related to the knowledge captured and exchanged and to the learning process and content. The KNOWLaboration tool follows and supports a participative decision-making process, to capture the opinion of as many members as possible, with an increased interaction between them before the actual decision-making sessions. This collaborative platform has the potential to facilitate the decision-making process and allow intensive communication among a large number of individuals and organizations.

Discussion

From our experience and interaction with real users during the development of KNOWLaboration, we have derived a constructive set of recommendations for effectively deploying IT in such networks. These design principles are not recipes, but rather embody our understanding of how modern IT can help learning networks.

The first recommendation highlights the need to support the three main learning network management processes: (1) The initiation phase concerns itself with the setting up of the learning network. The IT tools should provide a detailed checklist with potential community-initiators, mechanisms to identify the type of members that such a community would require, and planning facilities to ensure the workability of the community. (2) The maintenance and improvement phase

be referred to as a market transaction. This market approach brought in by the media reference model is useful in order to model the knowledge transactions as market transactions between market participants in various roles. Furthermore the market approach is particularly suitable for modeling knowledge networks with a commercial dimension, as per *Figure 1*.

Conclusions

The new knowledge-based economy necessitates increasingly the collaboration between different organizations. Despite the recent upsurge in e-learning and knowledge management systems, the vast majority of these systems focus on either individual users or individual organizations. This chapter introduced the concept of knowledge networking at the interorganizational level, presented a typology of knowledge networks, demonstrated how the different modes of knowledge conversion can be supported by information and communication technologies, and presented our experiences and lessons learned from developing two IT toolkits for two types of knowledge networks.

Acknowledgments

The chapter is largely based on the research findings that have taken place at the framework of three European Commission-supported projects:

- *WIT*: Enabling Data Sharing and Business Interactivity Across the Wood-Sector Value Chain by Developing a Custom Set of Internet-Based IT Tools;
- *INKASS*: Intelligent Knowledge Asset Sharing and Trading; and
- *KNOWLaboration*: Knowledge Applications for Collaborative Interorganizational Networks.

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for IT facilities that assist in the direction of providing connections to the world, including what is happening, what is hot in the field, new developments, new technologies, evaluation and reviews, external experts, reference material, news and announcements of external events, directory of external experts, links to other sites, and library of references.

Learning networks usually have members who take an active role in cultivating the community and may participate in the decisions that affect the operation of the network. The sixth recommendation is about offering a variety of administrative tools to monitor and configure the use and effectiveness of the network space. Typical features of this kind include logs and statistics for monitoring, polling and voting facilities, assessment tools and surveys, performance indicators, and finally switches and policy enforcement algorithms.

Future Trends in Knowledge Networks

We have outlined in this chapter various types of interorganizational knowledge networks and discussed in detail two of them (knowledge supply chains and learning networks). In these two types of knowledge networks, knowledge assets are exchanged in order to increase the efficiency of the supply chain and learning and competencies of the participating organizations. But, what other ways are there for an organization to exploit its knowledge assets? Can firms sell knowledge assets, creating “smart” offerings that embed such assets, or develop knowledge-based products that embody knowledge assets? Which are the most appropriate pricing mechanisms for these offerings? How can they be promoted? How can they be organized and sold in an electronic marketplace? What are the points of view of the customer (needs met) and the supplier (return on investment) as well as the impacts such an approach to products has on its related processes?

These are some of the questions we explore in INKASS, a recent research program on knowledge-asset-trading network development (see Apostolou et al., 2002). Our research attempts to extend the traditional Internet-based marketplaces (e-marketplaces), which improve overall market efficiency; reduce transactional costs by integrating sourcing, purchasing, and billing; provide wider choices of buyer and selling trading partners; centralize access to information; and allow for pricing that better reflects supply and demand (see Aberdeen Group, 2000; Archer & Gebauer, 2001; McKinsey, 2000; Mohan, 2000). The research explores the development of knowledge-trading marketplaces, i.e., marketplaces that provide the digital community context where knowledge seekers can find knowledge providers (see, e.g., Kaieteur Institute, 2001).

Despite related research work, current virtual knowledge-trading marketplaces exhibit major limitations. They emphasize the explicit dimension of knowledge assets, thereby ignoring the complex context and content features that determine the applicability and usefulness of knowledge in a given situation. Moreover, they do not consider the fact that the real power of electronic marketplaces lies not in copying ways of working already known from traditional business, but in exploiting the strength of synchronous and asynchronous community building. Finally, they limit their focus to the technical issues and do not take into account business matters like customer relationships, advanced revenue models, alternative pricing mechanisms, etc.

Further research should aim to address the above shortcomings. For instance we have initiated an effort to build a solution for knowledge trading that spends due diligence to both technological and methodological developments and investigates long-term issues like creation of trust and customer satisfaction.

The first research stream refers to the explicit description of supply and demand and the matchmaking between both. Since knowledge is by definition highly context-dependent, all explicit representations (at the seller side) will necessarily decontextualize it to some extent. In addition, in a knowledge e-marketplace we need sophisticated representations of products and customer needs, which should also express aspects like knowledge quality and knowledge actuality, which can hardly be dealt with in a general manner. In our approach we use a knowledge-rich, ontology-based formalization of information objects and the domain of application as the backbone of our matchmaking system (see, e.g., McGuiness, 1999).

A second research direction refers to the analysis of the knowledge network as a medium of interacting agents. Although the Nonaka and Takeuchi knowledge management approach used herein models sufficiently the interactions (or modes of knowledge conversion) that occur during knowledge transactions within knowledge networks, it is not sufficient for modeling knowledge networks as media of interacting actors that exchange knowledge over space and time. It is neither capable of providing a methodological basis for modeling the community of the network and the business processes of the network and for developing the infrastructure required for the operation of the network. To address these shortcomings we may consider a knowledge network as a medium in between a sender and a recipient that enables communication between these two parties. In order to structure and describe aspects and components that have to be taken into consideration for knowledge networks as e-media, we are working towards integrating the Nonaka and Takeuchi model with the media reference model (see Apostolou et al., 2002; Schmid & Lindemann, 1998) for describing e-media. According to the e-media approach of knowledge networks, agents interact with the medium in order to exchange knowledge assets. This interaction process can

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Endnotes

- ¹ The consulting business itself intrinsically contains this concept of integration, syndication, and melioration of knowledge. Most of the concepts provided by consultancies have their origin in academic sources. Consulting firms translate, package, and apply these types of knowledge in problem spaces and languages of companies and organizations.
- ² www.twi.co.uk
- ³ P2P networking has the capability to facilitate sharing of resources that include human expertise, insight, rules-of-thumb, and lessons learned, not just files (Tiwana, 2003). They can potentially support the “socialization” mode as well, although we are not aware of any applications that exploit P2P networks to support exchange of tacit knowledge.
- ⁴ The sixth stakeholder of learning networks (policy makers) is currently not supported by KNOWLaboration.

Chapter VIII

Networked Collaborative E-Learning

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Abstract

This chapter introduces networked collaborative e-learning as a specific model of e-learning. It argues that any e-learning event or course is underpinned by a set of educational values which determine the design of that event, and that networked collaborative e-learning is underpinned by a belief that e-learning communities and identity formation are central features of this form of learning. The author believes that an understanding of the educational benefits and theoretical constructs of this form of learning will inform our practice of e-learning and point to new areas of research in this new and emerging field.

Overview of the Chapter

This chapter examines a wide-ranging set of issues relating to the effective implementation of networked collaborative e-learning in continuing professional development and adult learning contexts. It aims to show that:

- Our view of learning often determines how we approach any learning and teaching event. Our values and beliefs and the context in which we work define what is important and what is not. This has consequences for the work of organisational trainers and developers.
- We have to actively and consciously design for networked collaborative e-learning. Providing learners with access to the technology does not in itself lead to the technology being used or to learning taking place. There has to be a good reason for learning in this way, and we have to provide well-designed and supportive e-learning environments designed to facilitate effective learning.
- A new paradigm of learning — which I refer to here as networked collaborative e-learning — is emerging as a new model for designing e-learning events.
- At the heart of these changes is a belief that e-learning communities (which can take the form of communities of practice, research communities, and learning communities) and identity formation in these new virtual environments are central features, which need to be considered in order to make them effective and productive places in which to learn.
- A central feature underpinning this view of e-learning is the benefit of collaborative evaluation and assessment in e-learning. When we ask learners to learn collaboratively, we must also ensure they have every opportunity to evaluate their learning in similarly supportive, collaborative contexts.
- In order to attain effective networked collaborative e-learning, it has to be facilitated by teachers and trainers sympathetic to openness in the learning process and who work towards providing an environment supportive of a high degree of self-managed learning.

Networked collaborative e-learning is therefore a form of e-learning that emphasises bringing together learners via personal computers linked to the Internet, with a focus on them working as a “learning community,” sharing resources, knowledge, experience, and responsibility through reciprocal collaborative learning.

Introduction

The advent of electronic communications, the Web, the Internet, and associated technologies have produced a climate in which e-learning is seen as a means towards improving training and development opportunities for people in organisations. There is no one accepted uniform methodology to explain how a move to e-learning could benefit organisations in both the short and long term (Ash & Bacsich, 2002). And even though the business models for e-learning are not yet proven (Ryan, 2000), many organisations (including higher education institutions) are making plans to globalise their training and development provision (Middlehurst, 2000). In this context, most e-learning is being developed in the form of short e-training courses delivered as stand-alone packages. But complex organisational problems and issues (and more complex higher order learning, generally) are not amenable to this form of packaged e-learning. This chapter therefore addresses the needs of organisations in focusing on complex learning via e-learning systems and processes.

A missing element in the provision of e-learning is a concern with the design of e-learning events and courses. We need a thorough understanding of high quality design approaches needed in order to implement and sustain e-learning in ways that lead to quality learning processes and outcomes.

One of the main ideas underpinning networked collaborative e-learning is that the interactions between professionals are a significant aspect of their meaningful, intentional, planned development. When professionals interact with each other and available resources, they change. For example, such changes may occur in their *abilities, attitudes, beliefs, capabilities, knowledge and understanding, mental models, and skills* (Spector, 2000). These changes may reside in the individual, or in the group, or at the organisation level. Furthermore, they may be enhanced by the supportive interaction of the individual and the group in which she or he resides. In attempting to plan and then support meaningful, intentional learning we need to understand the context in which it develops best. This idea is underpinned by the early researches of Vygotsky (1962, 1978) into the importance of experiential settings and social contexts for the development of understanding. Such understanding is clearly important to the management of any professional development e-learning course or event.

A second key idea is that networked e-learning environments can provide a valuable way of supporting such interactions. There are now many software systems, of both Web-based and stand-alone types, that can support communication between group members (see <http://www.shef.ac.uk/collaborate/> for an extensive survey of these; see Barajas & Owen, 2000; Bringelson & Carey, 2000; Seufert, 2000 for specific examples and theoretical design considerations). Indeed, it is commonly suggested (Sklar & Pollack, 2000) that there has been a

general paradigm shift in Internet usage, from a vast reference source or virtual encyclopedia to a set of virtual communities. In other words, that communication between people has become the dominant mode of use. These two key ideas, that of learning in groups and communities and communicating in networked environments, come together in the notion of networked collaborative e-learning (Banks et al., 2003).

It is appropriate that, in the context of a book which has a focus on electronic business, I should draw on a perspective of e-learning which comes from organisational and management learning, adult learning, and the sociocultural tradition of learning and training. These are the key areas most likely to be meaningful to those in the global electronic business sector and most likely to offer important insights into the potential of networked e-learning in the practice of global business. In this chapter I write from the perspective of an e-learning practitioner and researcher and assume that my audience is made up of like-minded people who are interested in implementing e-learning and researching their practice. Although there is still much to be learned in this new and emerging field — cultural differences in approaches to learning and teaching in a global e-learning context being one of them — we can, with a degree of certainty, begin to provide a vision for networked e-learning that works towards inclusion of people from different traditions and cultures.

Views of Learning

To start with, I will endeavour to indicate how our view of learning often determines the way we design e-learning events and courses and show that this has serious consequences for learning outcomes. For example, many teachers and trainers approach e-learning from the viewpoint of instructional system design, which views learning as a rather passive activity. Learning is seen as a form of “computation.” This point of view often leads to learning designs that do not support critical, interactive learning experiences and do not consider the complexities and uncertainties of the development of professional practice in the learning process. From this point of view, learning is often solely considered in terms of cognitive processes and conceptual structures.

If, however, we design for learning that is interactive and which occurs in social settings such as groups and communities, we are led to ask the question: *What social engagements and processes provide the “proper” context for learning?* Learning is also often conventionally viewed solely as the acquisition of propositional knowledge by individuals. But what happens to our practice when we view learning as social co-participation and knowledge building?

I want to show that learning is a process that takes place in a participation framework, not solely in an individual's mind, and that learning is a way of being in the social world, not a way of coming to know it. There is of course a link between being in the world (ontology) and knowing about the world (epistemology). Knowing about the world affects how we live in the world, and how we are in that world likewise affects how we think about it.

Following from this, I want to show that in designing sustained, purposeful networked collaborative e-learning, it is necessary to take a view of learning that requires a participatory design, which involves an understanding of social constructionism and knowledge building; the development of communities of e-learners; situated learning and the character of practice; and problem-based, exploratory, collaborative, and critically reflective learning.

What Is Networked Collaborative E-Learning?

Many terms are emerging to describe the use of electronic communications and the Internet in education and training. My preference is for "networked collaborative e-learning" since it places the emphasis on networking people and resources together and on collaboration as the major form of social relationship within a learning context. The emphasis is emphatically on "learning," and not on the technology.

Networked collaborative e-learning is therefore the bringing together of learners via personal computers linked to the Internet, with a focus on them working as a "learning community," sharing resources, knowledge, experience, and responsibility through reciprocal collaborative learning.

The Context of Learning

E-learning does not occur out of context. It is embedded in the wider context of any educational, training, or development endeavour where values and beliefs about appropriate forms of learning are explicitly and implicitly addressed in the design of the learning event. This has consequences for the work of organisational trainers and developers and for learners.

The kind of e-learning proposed here supports open adult learning and professional development where learners are able to work in small distributed e-learning groups and negotiate amongst themselves the focus of their work. In this form of e-learning, there are no specific predefined learning outcomes. Each group embarks on a learning-journey which requires collaboration but which does not define in exact detail how they should work together or what the

outcomes of their learning should be. In this respect, the groups are following a long tradition of adult learning which supports openness and exploration (Boot & Hodgson, 1987; Cunningham, 1987; Harris, 1987) and which has a history in experiential learning groups (Davis & Denning, 2000; Reynolds, 1994).

This form of e-learning emphasises the educational need for learners to work in social learning environments which emphasise both the situated nature of learning (Koschmann, 1996; Lave & Wenger, 1991; Packer & Goicoechea, 2000; Salomon & Perkins, 1998) and the importance of coproduction and co-participation (McConnell, 2000, 2002a). This is linked to the capability of the Internet and the Web to support group work and provide a virtual environment for learners to work together, share resources, and collaborate. Within this virtual learning community perspective, learners have opportunities to have a wide choice over the content and direction of their learning and the management of their own learning. They can also cooperate with others in their learning through processes of negotiation and discussion. Learners working in these environments are encouraged to take a critical perspective on their learning with strong relationships to their professional practice and to focus on their own learning and development from a critical, reflective perspective, combined with an understanding of relevant concepts and ideas.

The Benefits of Collaborative Group Work in Learning

The benefits of collaborative and cooperative learning are well documented (e.g., Johnson & Johnson, 1999; McConnell, 2000; Sharan, 1990; Slavin, 1990; Slavin et al., 1985; Stahl, 2002; Thousand, Villa, & Nevin, 1994). In their work into the relative impact on achievement of competitive, individualistic, and cooperative learning efforts, Johnson and Johnson (1990) looked at 323 studies. Their conclusions indicate that cooperative methods lead to higher achievement than competitive or individualistic ones when measured by a variety of possible indices. They used four indices of achievement:

1. *Mastery and Retention of Material.* Learners in cooperative learning environments perform at a higher level than those working in competitive or individualistic environments (Johnson & Johnson, 1990). When achievement in “pure” cooperative groups is compared with achievement in groups using a mixture of cooperative, competitive, and individualistic learning methods, the results show that the “pure” methods consistently produce significantly higher achievements.
2. *Quality of Reasoning Strategies.* Individuals working in cooperative groups use focusing strategies more often than those working competitively or individualistically. Learning problems are therefore solved faster. Those

involved in cooperative work also use elaboration and metacognition strategies (such as showing an awareness and self-control of learning) more often than those working in competitive and individualistic situations. Higher level reasoning is promoted by cooperative learning, and when comparisons are made between learners using cooperative, competitive, and individualistic learning strategies for tasks requiring higher or lower level reasoning strategies to solve them, learners in cooperative groups discovered and used more higher level strategy methods.

3. *Process Gains*. Process gains such as the production of new ideas and solutions are generated through group interaction. They are not generated when persons are working on their own.
4. *Transference of Learning*. There is a high degree of group-to-individual transference after working in cooperative groups, i.e., when individuals have worked in a cooperative environment, their learning is transferred to situations where they have to work on their own.

In general, it seems that at least four factors seem to influence cooperation in e-learning:

- a willingness by learners to participate in this form of learning
- an understanding by learners and trainers and teachers of the benefits of this form of learning
- an assessment system that supports and rewards cooperation and collaboration and the active involvement of the learner in their own assessment
- distribution of power between teacher/learner: the learner has to see in practice that they have power to control their learning (Hodgson & McConnell, 1992)

Networked Collaborative E-Learning: A New Paradigm?

Conventional e-learning poses some problematic issues in our relationships with learners and in the form of learning that is often encouraged. In conventional e-learning, the content of learning material is largely unilaterally decided on by trainers, developers, or academic staff. Learners have little if any say in the content of the course, and teachers determine the focus of what is to be

addressed as learning and package this into self-study material. The use of behavioural objectives and the reliance on instructional design principles reduces the complexities of learning to a set of predefined outcomes. Learners are led into reducing their learning to fit someone else's criteria. Knowledge, in this packaged form, is slow to be changed and "updated"; it often takes several years before changes are made to the material. Yet access to "just-in-time" knowledge is an increasingly important feature of our society today. The form of learning encouraged and rewarded in this conventional form of learning is inherently individualistic: the learning arrangement is largely that between teacher and learner. It is difficult to establish contact, interaction, and discussion between learners as a group and indeed between the teacher and each individual learner. Learning rarely takes place in a social context where learners and teachers can discuss, share, and explore in-depth issues relating to learning.

Related to the above is the problem of isolation in conventional e-learning programmes. It is my experience that many learners rate this as one of the major drawbacks of this form of learning, and it is often a reason for learners withdrawing from such programmes. It is also the case too that many course providers running such programmes find the experience isolating. Assessment in conventional e-learning is unilateral, carried out solely by the teacher. This has serious implications for the form of learning engaged in and for the learners' orientation to learning. With control of assessment firmly in the hands of teachers, learners often work instrumentally to seek cues about the best way of passing a course of study, sometimes to the detriment of their learning (Becker, Geer, & Hughes, 1968; Miller & Parlett, 1974). The educational technology of conventional e-learning largely supports a form of positivism in relation to knowledge ("positivism is a particular kind of 'identity thinking' which tries to grasp and subdue the complexities of reality by imposing definitions and operationalized categories specifically in the interests of control"; Harris, 1987). I would agree with Harris in the argument that, despite good intentions, producers of distance learning packages and e-learning packages often engage in "providing technologically productive knowledge ... a technicization of education" (Harris,).

New information and communication technologies offer new opportunities for innovation in the learning process. In comparison with conventional e-learning, the starting point of networked collaborative e-learning is the learning interests and concerns of the learners, rather than a concern with presenting to learners the knowledge and information held by the teacher or that deemed to be the knowledge of the field of study.

Collaborative learning can be highly developmental, engaging the learner in making sense of their learning and in reconstructing knowledge. It emphasises constant critical reflection within a social context where peers and teachers help

each other make sense of their learning. By comparison, traditional forms of learning are concerned more with transmitting largely predefined forms of knowledge with little if any connection with personal experience and critical reflection.

Networked collaborative e-learning is based on a set of beliefs concerning the purposes of learning; the relationships between the learner and teacher and between each learner; and the use of new advanced information and communication technologies. A few observations can be made in relation to this:

- *Networked collaborative e-learning is based on principles of action learning and action research.* The focus of study is largely problem centred (e.g., a focus on issues in professional practice or on issues in personal, experiential learning). Learners should have as much choice as possible over the direction and content of their learning. They arrive at the focus of their studies through discussion and negotiation with other learners and teachers.
- *It is based on critical reflective learning in a social context.* Networked collaborative e-learning technology supports group discussion and the sharing of experience. A social, conversational context is important in the process of learning since it supports the clarification of ideas and concepts through discussion; develops critical thinking; provides opportunities for learners to share information and ideas; develops communication skills; provides a context where the learners can take control of their own learning; and provides validation of individuals' ideas and ways of thinking (through conversation, multiple perspectives, and argument; McConnell, 2000). A critical perspective on learning is therefore part of the process of networked collaborative e-learning. The critical perspective derives from reflection on one's own learning; the conversations one has concerning one's own and other participants' learning; and the relationship one has with any academic (or public domain) material engaged with in the process of learning.
- *Collaborative assessment is a necessary component.* A critical perspective is also necessary in the assessment process, and in keeping with the purpose of networked collaborative e-learning, assessment should involve the learner, their peers, and a teacher. This is called triangulated assessment (McConnell, 2002c). The need for and importance of collaborative assessment is clearly articulated by many learning practitioners.
- *It involves a community of learners.* Learners are responsible for managing their own learning and for helping others in theirs. The learning

community works through learners and teachers collectively managing their learning needs through negotiation and discussion (Pedler, 1981).

- *It supports just-in-time knowledge.* Knowledge in networked collaborative e-learning comes from several sources, such as knowledge from other learners in the process of discussion; knowledge from cooperative learning projects; knowledge from online sources and resources; and knowledge from academic papers and books. However, the concept of just-in-time knowledge is central. There are at least two processes underpinning the development of just-in-time knowledge. The first is “communication” where the focus is on exchanges and collaborative learning. The objective is to allow knowledge building through social interaction. This form of learning puts learners in contact with each other. The constitution of a learning group is central and requires a common project to work on. The focus, however, is still on personal learning. The second process is “knowledge building,” and the focus here is on collective knowledge building from exchanges between learners about their practices. This builds on the concept of communication but requires some specific conditions, such as:
 - A shift from “trivial” conversation to an organised debate that has much to do with a structured collective research approach.
 - The expertise of others should be acknowledged without requiring external validation.
 - The debates should not be concerned with taken-for-granted patterns of interpretation but should focus on the transformation of behaviours, habits, or routines. This requires time and is rarely compatible with day-to-day (on-the-job) practice.
 - The debate requires an incentive in terms of intellectual commitment. Participation in a collaborative task helps maintain efforts to keep up the level of exchanges in the debate. This task could be an exercise such as writing a joint paper, setting up a professional knowledge resource base, or realising a collective research project (Saunders et al., 1994).
- *It requires collective responsibility by learners and teachers.* Learners and teachers need to attend to the processes of the community, i.e., reviewing and modifying the design, procedures, and ways of working.

In imagining the design of e-learning, it is useful to ask what kind of learning context might suit learners in public or private sector organisations. Bonamy and Hauglusliane-Charlier (1995) suggest three views of virtual learning, which may be used for professional development purposes:

- *The Virtual Classroom as the Focus:* Here, the control of learning is placed firmly with the teacher or expert. The emphasis is on knowledge acquisition with little concern for participant interaction or for social negotiation of meaning. There is a “body” of knowledge to be transmitted, and learners are expected to study it, learn it, and mirror it back to the teacher in some way, usually by formal examination.
- *The Communication Process as the Focus:* Here the control and responsibility for learning resides with each learner, who is perceived as an “expert” in their own way. Knowledge is constructed via social interaction in the online learning environment. The teacher acts as moderator or animator.
- *Knowledge Building as the Focus:* The focus here is on individual and collective knowledge building. There is reification of professional knowledge from the collective expertise of the participants. The teacher acts as cognitive expert and helps in the development of an “evolving knowledge base.” The main application of the knowledge building focus is professional learning and development.

From these three views of virtual learning, three broad models of learning can be hypothesised, based on a set of characteristics such as the underlying view of knowledge, the processes of learning, the role of the teacher and learner, and so on. The three models are:

1. the transmission/dissemination model
2. the transmission plus discussion model
3. the learning community model

By reference to such models (see *Figure 1*), we can consciously make choices about the kind of learning we wish to foster in any e-learning context.

When these three e-learning designs are evaluated, it can be shown that different designs produce different levels of participation and collaboration, and collaboration and discussion do not occur on their own — they must be central, sustained aspects of the course. In addition, intended processes and outcomes are not always achieved as planned, and familiarity with the technology does not in itself lead to participation or learning. Frequent participation (daily/weekly) is needed to sustain interest and to ensure the course or learning event is perceived as being “useful.” It does not appear difficult for participants in networked e-learning to “use” online material or online resources. Finally, different course designs may have an effect on the learner’s motivation to learn (McConnell, 2000).

Figure 1. Three Models of E-Learning

	MODEL 1 Transmission/ Dissemination	MODEL 2 Transmission With Discussion	MODEL 3 Learning Community
UNDERLYING VIEW OF KNOWLEDGE	Knowledge exists independently of the learner. A “curriculum” is put together by the teacher and is learned by the learner. Interpretation can be very limited or not expected.	Knowledge exists independently of the learner. A “curriculum” is put together by the teacher and is learned by the learner. Limited room for interpretation and creativity.	Knowledge is constructed collectively. There are multiple “truths” and interpretations. Learning is problem based or issue based.
LEARNING PROCESSES	Learner receives material and is expected to learn it on their own. Individualism. Transmission or dissemination.	Learner receives material and is expected to learn it. Some discussion occurs but is directed by teacher, who poses questions to be answered.	Learner poses problems or issues about their practice as a source of learning. Social, collaborative, dialogical learning.
ROLE/VIEW OF LEARNER	Passive receiver of knowledge. All learners are viewed as the same—they are given the same learning material.	Learners receive knowledge and are asked to show their understanding of it. Learners are required to learn the same material.	Active constructor of own learning. Viewed as diverse individuals/expert professionals.
ROLE/VIEW OF TEACHER	Teacher is “expert,” controller, and arbiter of knowledge.	Knowledge holder, “expert,” moderator.	Facilitator, learner, critical observer, co-expert.
ASSESSMENT	Unilateral by teacher. External criteria used. Exams given.	Unilateral by teacher. External criteria used. Exams plus assignments given.	Collaborative self-peer-teacher assessment used. Both learner and teacher criteria applied.
LEARNING OUTCOMES	Graduation. Some personal development.	Personal and professional development.	Creation and sharing of expertise. Personal and professional development.
ICT USED	Web. File transfer.	Web. File transfer. Web/e-mail discussions.	Groupware. Virtual learning environments. Extensive Web discussion forums. Bespoke collaborative learning environments.
METAPHOR	Classroom. Filling an empty jug.	Classroom plus seminar.	Learning community.

Designing for Networked Collaborative E-learning: Model Three

In designing for Model Three learning, some guiding principles are needed. These include the need to consider the nature of learning in professional organisational contexts.

The Nature of Learning in Professional Organisational Contexts

Typically, in any lifelong learning or organisational learning context where complex higher order learning takes place in groups, a variety of characteristics are exhibited which have to be taken into consideration in the design and implementation of any networked e-learning event (McConnell, 2002b). These are:

- The problems and issues addressed should be defined by the groups themselves through processes of negotiation and discussion. The problems are usually complex and are usually ill-defined, which makes for fertile ground for the production of mutual understandings and the construction of “shared resolutions” (Schon, 1983).
- The problems and issues often have a personal and professional focus: They are important to the members of the group, arising from concerns and interests they may have about their professional practice or about their organisation. The outcomes associated with the group work will be of benefit to the members in their professional practice or to their organisations.
- The problems or issues require negotiation and communication to understand them. Because the issues researched are invariably complex and ill-defined, the members of each group have to engage in considerable communication in order to understand them and in order to negotiate changes in their perception of the “problem” and its resolution as their work progresses. Communication is both task oriented and socially centred. The groups can function both as learning communities (Pedler, 1981; Snell, 1989) which have an interest in sharing, supporting, and learning collaboratively in a social context and as communities of practice (Wenger, 1998) in which members are actively constructing understandings of what it means to be professionals in their own field of interest.
- Problems of this kind are often best investigated by adopting an action research perspective. Members of the groups can be encouraged to view their learning as “action research” (Carr & Kemmis, 1986; Elden &

Chisholm, 1993; Whitehead, 1989; Winter, 1989). This provides them with a model of how to work together, which helps guide them in their collaborations.

- The members of the groups go through a journey of learning: There are no specific predefined learning outcomes. Each group embarks on a learning journey requiring collaboration but which does not define in exact detail how they should work together or what the outcomes of their learning should be.
- The work of the groups involves each member in a high degree of reflexivity: Learning in these groups is highly experiential, and the groups should therefore be encouraged to be reflective and to use this as a source of learning (Boud & Walker, 1998; Moon, 1999).

A means for achieving the above is exposure to other learners' development within the learning community. Members participate in developing the learning community perspective, which is based on participants and teachers/trainers taking collective responsibility for the design and evaluation of the event, via constant review and modification of the design, procedures, and ways of working.

In order to attain this, McConnell (2000) emphasises the need for a high degree of openness in the educational process and forms of learning that are largely self-determined. There has to be a real purpose to the cooperative process alongside a supportive e-learning environment (such as a virtual learning environment or groupware) that supports community learning. These are parts of a whole which, taken together, suggest a philosophy of and a set of procedures for the design of e-learning environments.

E-Learning Communities and Identity Formation

In designing for Model Three learning, which is based on knowledge sharing and building, we are implicitly designing for learning that takes place in groups and communities. This requires a fundamental shift in our perspective as teachers and trainers, as suggested by the characteristics of Model Three discussed above.

The current interest in Internet-based communities (e.g., Jones, 1995; Rheingold, 1993) might in part be explained by our need to feel we belong to a group of like-minded people — people who share a set of values and beliefs about the world

we live in. In educational circles, the idea of community has been a central design feature of many lifelong learning practitioners. A learning community is one where the focus is on members supporting each other in a culture of learning. The community tries to work towards shared understandings. There have been many attempts to characterise learning communities in the educational literature (see, for example, Beaty, Cousin, & Deepwell, 2002; Fox, 2002; McConnell, 2002b; Paloff & Pratt, 1999; Perriton & Reedy, 2002; Renninger & Shumar, 2002; Reynolds & Hodgson, 2002; Smith & Kollock, 1998; Wenger, 1998). A key feature of the idea is that responsibility for learning is “shared” among community members. No one individual is responsible for knowing everything; rather, the shared knowledge and skills are distributed among members. Individually, each contributes to the group endeavour, enabling the group to accomplish more than the individual members might separately, with the key gain of deepened understanding of both content and processes by individual members of the group.

The move to Web-based e-learning and teaching is now exercising the minds of those involved in continuing professional development in public and private sector organisations (see, for example, Dirckinck-Holmfeld & Fibiger, 2002; Dirckinck-Holmfeld et al., 2003). A key question to answer is: How do we design distributed networked e-learning so that it supports those values and beliefs of learning communities we hold to be so central to our practice? Those involved in this field are increasingly becoming interested in the effect of this kind of learning on identity formation and change and on how we can understand this and use it within organisational contexts.

What is identity? Wenger (1998, Chap. 6) suggests that we experience identity in practice: It is a lived experience in a specific community such as those we work in or those we learn in. We develop identity by looking at who we are in relation to the community in which we are practicing members. Practically, this occurs through participation in the work of the community.

Members of communities of practice are likely to belong to multiple communities at the same time. As they experience this multimembership, they have to work at maintaining their identity across the boundaries (Wenger, 1998, p. 158). This can have beneficial effects on their learning. They are often forced to reflect on their identity in those different communities, and if this is used as a source of learning and development, they may use the opportunity to realign their identity formation. This can be a powerful learning experience.

A Working Example

I have shown elsewhere (McConnell, 2002a) how this phenomenon may unfold in collaborative e-learning communities. The context is a two-year global

carried out in the knowledge of who the community is. It is carried out by individuals who “imagine” themselves to be part of this virtual community. Their discussions about their collective work are carried out both as a way of communicating about “content,” processes, and other aspects of the community’s work, but also as ways of communicating about who they are as individual participants in this community. The identity of each member is revealed in the work and communications within the e-learning community.

The negotiation of identity is a very reflexive thing. Members of e-learning communities of this kind reflect on their group experiences throughout the course of their work. They take advantage of opportunities where they can formally “stand back” and review their own and each other’s communications and contributions to the work they are all involved in. This can be a very revealing, challenging, and risky activity for them to have to do. Identity — of self and of groups — is something to be creatively worked at in order to be sustained, as Anthony Giddens (1991, p. 33) has pointed out:

The altered self has to be explored and constructed as part of a reflexive process of connecting personal and social change.

Identity Construction

Within Model Three collaborative e-learning communities, considerable personal and social change can occur. Within these communities, each member’s identity is presented, challenged, and reshaped with respect to:

Themselves as Learners: As learners they are challenged to change their identity as learners by:

- taking responsibility for developing skill in judging the quality of their own and each other’s work
- identifying as a member of a new e-learning community of practice
- understanding that assessment is a learning process and not a unilateral process of judgement
- writing for a definite audience, i.e., the community of peers and teachers
- coming to view each other as an important source of expertise and learning
- coming to realise that they can produce knowledge

professional development master's programme which is run completely via the Internet (see <http://www.shef.ac.uk/e-learning/>).

The members of the e-learning community work closely on a variety of self-chosen problems and issues relating to their professional practise. This is carried out mainly in a virtual learning environment called Web-CT. Their discussions involve reflection on their professional practice and critical discussion and analysis of theory and concepts related to the particular problems being investigated. What each member learns from participating in the work of the community is taken out of the community and into their professional practice context, where it is applied, tested, and reflected on. This process helps produce "development" in their professional practice (as teacher, lecturer, librarian, consultant, or whatever their current practice is). The insights and knowledge gained from this are then brought back into the ongoing work of the e-learning community, where it is used as content for discussion and where it eventually becomes material to be woven into the various products of their learning. This is an important facet of the knowledge-building work which takes place in the community. Sometimes participants are aware as they are doing it that they are developing knowledge in this way. Often they are not and it is only when they later collectively review their work that they gain some insight into this process. The weaving together of work around theory and practice becomes almost natural as the members of the group examine the literature and discuss it and relate it to their present e-learning community work and to their professional practice "back home." This process also works in the other direction, where their practice in the group and their practice as professionals become the catalyst for finding theory to help explain it.

The construction of identity is a central aspect of this kind of learning (Lave & Wenger, 1991; Packer & Goicoechea, 2000). It can be argued that when learning is viewed as social co-participation, the focus is on each individual constructing their identity within the social space of the learning community. This view of identity within learning is one which poses interesting questions about the "hidden" ontology of sociocultural theories of learning:

Whereas much psychological research treats identity simply as self-concept, as knowledge of self, that is, as epistemological, the sociocultural conception of identity addresses the fluid character of human being and the way identity is closely linked to participation and learning in the community. (Packer & Goicoechea, 2000, p. 229)

This occurs through (among other things) processes of social participation (Packer & Goicoechea, 2000; Wenger, 1998); more precisely, in this case, through processes of collaborative learning. The work of the community is

It also has the effect of changing members' attitudes to themselves as learners and seems to help them take responsibility for their own learning in the following ways:

- *Their Purpose as Learners:* Within this community they are asked to participate in a variety of activities and events which they do not normally associate with the purpose of learning, such as participating in collaborative assessment processes; taking some responsibility to help others learn; and reflecting on their learning and using that as a source of new learning.
- *Their Relationship With Teachers:* They are asked to take on some of the traditional responsibilities that they have come to associate with the role of a "teacher," such as assessing themselves and each other, and to develop relationships of a qualitatively different kind with their teacher, more akin at times to working with them as a peer than as a teacher. They are encouraged to talk with teachers as "friends," to challenge them and their expertise when necessary, and to share the power that teachers hold.
- *Their Place in the Academic World:* Learners often have strong conceptions of what it means to be "academic" and to participate on a postgraduate course. They tend to view the academic world as a place where individuals work alone and produce abstract, theoretical products. Some of them aspire to this. Some think it too detached and unrelated to the "real" world and therefore do not wish to emulate it. Being asked to work as a member of a learning community can produce conflict in their self-identity in a number of ways (this is a phenomenon noted by others, e.g., Lave & Wenger, 1991; Packer & Goicoechea, 2000), not least in their view of themselves in the academic world. It can cause them to question their views on the meaning of learning and scholarship. This is often a source of discussion in the group as they come to identify with the meaning of community and realise that it is possible to study as a community rather than solely as individuals.
- *Their Professional Practice:* The boundary between members' work in the group and their professional practice is a major source of change and development, both at a personal and professional level. Group members are challenged to consider their existing practice in the context of their work in the group. They are also challenged to consider their practice as learning members of the group. They discuss who they are (implicitly discussing their identity) as professional people (teachers, librarians, lecturers, course designers, etc.) and work toward "developing" their new identity. The work that occurs at the boundary of identity in the two communities can sometimes be highly developmental.

There is a tangible shift during the history of the group from seeing themselves as individual learners to seeing themselves as people learning in a social environment where collaboration and cooperation are expected and rewarded. All of this has effects on each member's identity as they shift from one community to another. The ways in which they experience themselves through participation helps them define who they are (Wenger, 1998).

Dialogue and Community

An example of this may help clarify what is involved and show how important it can be in the learning process. Cooperative and collaborative e-learning involves dialogue between learners and a great degree of interaction generally (Hodgson & Zenios, 2003). This increases the learner's grasp of conceptual material. In developmental terms, each learner who works closely with their peers will be exposed to situations where their own conceptual skills are stretched by the interactions with their peers. Their actual developmental level and their potential developmental level are narrowed by the interactions they engage in with their peers. This is called the zone of proximal development (Vygotsky, 1978, p. 86). Making this happen in e-learning environments is quite a challenge.

Working in a learning community (Hodgson & McConnell, 2002) involves new learning relationships:

It is not enough to learn how to direct one's own learning as an individual learner abetted by artefacts such as textbooks. Learning to learn in an expanded sense fundamentally involves learning to learn from others, learning to learn with others, learning to draw the most from cultural artefacts other than books, learning to mediate others' learning not only for their sake but for what that will teach oneself, and learning to contribute to the learning of a collective. (Salomon & Perkins, 1998, p. 21)

Developing and Sustaining Community

How does an e-learning community develop and sustain itself as a community? What I would like to do here is present an example of emergent research in order to illustrate some aspects of the work of e-learning groups and communities. It involves an examination of the ways in which the work of e-learning groups implicitly and explicitly helps to develop and sustain the groups as communities of learners. The question of what keeps an e-learning group working together

when there is no physical, face-to-face contact is an intriguing one. It is a central question of concern about education and training in e-learning environments.

Developing a positive orientation to working together is a central aspect of group work. The first point to make is that we have to strive to make the level and quality of interaction, discussion, and collaboration in the e-groups as high as possible. The second point is that the design of any learning event and the way in which the technology of distributed learning is used to support the event are important factors. Extrinsic incentives to collaborate and work together — such as assessment systems that reward collaboration — are also central to keeping the group of learners together.

How then does an e-learning community sustain itself?

A major component of sustainability is the achievement of “milestones” in the work of the community. In my research I have identified that collaborative e-learning groups often work in ways which intrinsically sustain themselves. Their work has an ebb and flow to it, but there are often important points when they work towards producing a collective experience or product, which I call a “milestone”:

A milestone is a point in the work of the group when something pivotal occurs. Various kinds of milestones can be discerned, such as the group making a decision, members agreeing to adopt it and then proceeding to carry it out. Another kind of milestone is an event which focuses their work on one particular task and which seems to help them understand where they are with their work, and how to proceed beyond this point. Milestones are points in the work of the group when energy rises, and the group members often become excited and highly communicative. (McConnell, 2002a)

An example of a milestone may help illustrate their general importance. One e-learning group on the master’s programme decided to develop an intranet site in order to allow each member the opportunity to explore the many tools and facilities that intranets offer. In doing this they would experientially learn about using intranets. They then wrote a “story” about their experience, aimed at “selling” the idea to colleagues in their place of work who are unlikely to know about intranets and their potential educational benefits.

This activity — the Intranet Stories — was clearly an important event in the life of the group. It was the first time each member had taken time out to produce a piece of work to be shared with the others. In this respect it was therefore challenging as well as potentially risky. It brought a sense of excitement to their work and was highly motivating. Each story was posted on the Web-CT discussion forum over a two-week period.

From the analysis of the work of this group it is clear that the stories help in the development of the emerging identity of the group because it is the group itself who has chosen this particular activity to address. They have not been told to focus on this issue by any external stakeholder (such as a teacher). It is they who “own” it. In addition, each member has negotiated to focus on a particular aspect of the work which they wish to research and which is related in some important way to their professional practice. For example, Anne has chosen to work on the potential of intranets for supporting language teaching. Betty is researching the ways in which intranets can be used in nursing education. Michael is interested in the ways in which he can use intranets to support teachers in a virtual management education course and so on. This helps keep their work focused on authentic problems which have real relevance to their practice.

In this case, the community is thus forged through processes of self-management, sharing, and engagement with each other’s stories and the insights this affords into each other’s practice. The constant presence and availability of everyone online means that it is possible for them to continue discussing the nature of their work and the different perspectives that can be brought to it. As a milestone in the work of the group, the period of storytelling:

- Gives them access to new ideas and opportunities
- Helps them understand each others professional practice and the different contexts in which each member works
- Helps them “see” the diversity of their group and appreciate the importance and richness of this
- Offers members opportunities to discuss and share ideas, Web and other resources and insights into their practice
- Helps them set new goals for their work
- Allows them to redraft their stories on the basis of members’ comments and feedback

The achievement of the work associated with a “milestone” seems to be integral to the group’s development and to the production of the final collective product of which the development of the intranet is only one part. The achievement of milestones frees up the group to be creative, challenging, and at times risk-taking. With the achievement of a milestone the group often moves into a period of very focused, highly interactive discussion accompanied by a great deal of “offstage” research activity by each member. Achieving a milestone helps move the group forward.

From the analysis of the work of the groups, several kinds of milestones can be discerned, each having a particular purpose and impact on the group:

- *Decisions in synchronous chat sessions leading to agreements, which in turn lead to great activity.* Synchronous chat sessions provide an opportunity for the group to “convene,” focus on a specific topic, which has been agreed in advance in the asynchronous forum, and forge their identity as a group. Chat sessions often lead to increased activity in the asynchronous forum as the group picks up on points covered in the chat, elaborates their meaning, and discusses how to put their decisions into operation.
- *The production of artefacts* such as drafts of the product report and the design of an intranet site. The production of artefacts seems to serve the purpose of letting the group see, in some concrete way, that they are progressing with their project.
- *Sharing input to the production of documents*, such as the sharing of each member’s story of how they learned to use an intranet. These kinds of milestones galvanise the group and bring them together at one point in their journey.
- *The adoption of new forms of working patterns*, such as working in subgroups. Here the focus is on subgroups taking charge of particular tasks which the group has agreed are necessary in order to meet the requirements of the general collective task. Adopting new forms of work patterns serves to give subgroups permission to work alone.

Throughout the life of these e-learning groups, negotiation is a central process and can take many forms. The groups negotiate around the meaning of their enterprise, their identity, and the focus of the problem. They negotiate who should work on what and the timescales for producing the final product. The processes for communicating and working together are also issues that are negotiated in the groups.

The identity of the members of the group *with the group*, and the development of their own individual identity within the group, occurs through these complex forms of negotiation.

The process of becoming accountable to the work and purposes of the group has been described by Wenger (1998, p. 152) as a display of competence. This involves three dimensions: (a) *mutual engagement*: in which we develop expectations about how to interact, how to treat each other, and how to work together; (b) *accountability to the enterprise*: the enterprise helps define how we see the world of the community. We develop a shared understanding of it, its culture and how to participate in its values and activities. We know what we are

I have long argued that an educated person is an aware, self-determining person, in the sense of being able to set objectives, to formulate standards of excellence for the work that realises these objectives, to assess work done in the light of those standards, and to be able to modify the objectives, the standards or the work programme in the light of experience and action; and all this in discussion and consultation with other relevant persons. If this is indeed a valid notion of what an educated person is, then it is clear that the educational process in all our main institutions of higher education does not prepare learners to acquire such self-determining competence. For staff unilaterally determine learning objectives, learner work programmes, learner assessment criteria, and unilaterally do the assessment of the learners' work. (Heron, 1981)

What effects, if any, do self-assessment and peer assessment have on learners' approaches to learning? We know from research into the effects of assessment on learning that many learners are cue seekers: They actively seek out information about how they are to be assessed and they try to find out about aspects of the course which are likely to be addressed in the assessment process. This knowledge helps to guide them in what they focus their learning on and often determines what they study towards for the course assessment (Miller & Parlett, 1974). Indeed, it has been argued that learners' view of university life is largely governed by what they think they will be assessed on (Becker et al., 1968).

The importance of all of this in situations where learners work as collaborative and cooperative e-learners and where they are involved in collaborative assessment seems clear. If learners are actively involved in decisions about how to learn and what to learn and why they are learning and are also actively involved in decisions about criteria for assessment and the process of judging their own and others' work, then their relationship to their studies will probably be qualitatively different to those learners who are treated as recipients of teaching and who are the object of others' unilateral assessment. Because learners in cooperative and collaborative e-learning situations make important decisions about their learning and assessment, there will be no need for them to seek cues from staff about assessment or to seek to find ways of "playing" the system. They determine the system themselves, in negotiation with other learners and staff.

Ramsden (1988) points to the way in which assessment processes inform learners of what is important to learn and what is not:

The evaluation process provides a signal to learners about the kind of learning they are expected to carry out; they adapt by choosing strategies that will apparently maximise success.

there for. And finally, (c) *a process of negotiating a repertoire*: through constant membership of the community we begin to understand its practices, interpret them, and develop a repertoire of practice that is recognisable to members of the community. We make use of what has happened in the community as a way of achieving this.

According to Wenger, these three dimensions are necessary components of identity formation within the community of learners and lead to the development of competence. Meaning needs to be negotiated through dialogue and discussion. In communities of practice “meaning making” is negotiated through the processes, relations, products, and experiences of the community (Wenger, 1998).

Problem-based collaborative learning, as it occurs in this particular e-learning context, has an effect on and implications for the identity of course participants. The focus of learning is the boundary between the participants’ identity as members of the e-learning community and their identity as practitioners in their own professional fields. The action research approach, which is an important underpinning method supporting learning on the master’s, helps participants make links between these two boundaries. They are invited to act within the e-learning community and at the same time act within their practice. The boundary between the two may be distinct on starting the course but becomes blurred and intersects as participants move between the two communities.

Collaborative Assessment in E-Learning

The design of Model Three networked collaborative e-learning courses and events must also address the important issue of assessment. The case for involving learners in some form of self-assessment and peer assessment in higher education is well established (e.g., Boud, 1995, 2000; Boyd & Cowan, 1985; Broadfoot, 1996; Heron, 1981; McConnell, 1999, 2000; McDowell & Sambell, 1999; Shafriri, 1999; Somerville, 1993; Stefani, 1998; Stephenson & Weil, 1992). Learner involvement in their own assessment is an important part of the preparation for life and work. Surveys looking at self-assessment studies show that there is considerable consistency between marks assigned by teachers and learners in peer assessment and self-assessment situations (Falchikov & Boud, 1989), thus dispelling some of the criticism that learners are not able to effectively assess themselves and each other. Although by no means universal, there is now a wider belief in the educational and social benefits of self-assessment and peer assessment.

Some form of self-assessment is also part of a philosophy of or approach to learning that seeks to work with learners as self-managing people who can take responsibility for their own learning:

In collaborative assessment environments, the expectation is that learners will engage in helping each other develop, review, and assess each other's course work. It is the collaborative learning and assessment process itself that signals to the learners what form of learning is expected (McConnell, 2002c). It can therefore be anticipated that collaborative assessment will be a central process in networked collaborative e-learning and will influence participants' relationships to learning. In such a context it might be expected that learners will adapt to a learning situation that requires them to share, discuss, explore, and support.

How does this work in practice, and what do learners think about this form of assessment? Assessment often determines learners' orientation to learning. If assessment is summative and unilaterally carried out by the teacher, learners often seek to find out what the teacher is looking for and work towards that. In networked collaborative e-learning we must design forms of assessment which support and reward cooperation. The need to get assessment "right" in these contexts cannot be over emphasised. Collaborative assessment strives to bring different viewpoints, and therefore different values, to the assessment process and in doing so helps to make the process of assessment more open and accountable (McConnell, 1999, 2002c).

Assessment should be part of the learning process on any collaborative e-learning course and should form a major part of the content of the course (by this I mean that assessment should be seen as a formative learning process). In these contexts, participants' course assignments are submitted for triangulated assessment, i.e., assessment where they, their co-workers in the learning group, and the group teacher read, comment on, and assess the assignment. This approach to assessment is consonant with and supports the overall aims and values of collaborative e-learning. In one study (McConnell, 2002c) it is shown that learners involved in networked collaborative assessment actively and critically reflect on their learning and on the benefits of collaborative assessment. It also shows that the new Web-based electronic learning environments are well placed to support the complexity of this form of assessment. The architecture of networked e-learning systems such as Web-CT supports learners in the reflective learning and assessment process.

The openness of the collaborative assessment process is crucial to its success. Whereas most assessment techniques are closed, involving only the learner and their teacher, collaborative assessment has to take place in an open environment (cf. Ames, 1992 [as quoted in Boud, 2000], who thinks all feedback should be private). Learning relationships have to be fostered and trust developed and maintained in order for collaborative assessment to succeed. The balance between critique and support is very important, yet at times very fragile. Peers and teachers are involved in collaborative learning and support throughout collaborative e-learning. But they are also called on to review and assess each

other's work. In a learning community or community of practice this is not only possible but it is desirable. The community has to be able to reflect on its work and be critical of each member's learning. Participants are aware of the possibility of deluding themselves. But the openness of this form of assessment, when carried out thoroughly and conscientiously, maintains a strong check on that.

Research shows the importance learners attach to learning and assessment processes which take place in a social environment (McConnell, 2002c). This is a major theme constantly referred to by learners. It is not only a major factor in supporting and motivating distant, distributed learners and in helping them overcome feelings of isolation: It also points to the benefits of social constructionism and social co-participation in learning, especially in lifelong learning and continuing professional development contexts. Not only do adult learners enjoy learning in social settings, they are quick to appreciate the potential benefits afforded by collaboration in the learning and assessment process. No less so in networked collaborative e-learning environments.

Challenges in the Facilitation of Networked E-Learning

It will have become clear that in developing Model Three networked e-learning, practitioners have to adopt new relationships with learners. They have to liberate themselves from traditional notions of teaching and instructional design which focus on *teaching* and move towards those that focus on facilitating *learning*. This will be a major challenge: for practitioners and organisations alike.

A major factor in the effective uptake of e-learning in organisations will therefore be the professional development of trainers, course developers, and teachers in this new form of learning provision. Those involved in providing e-learning require help in making the paradigm shift from "conventional" teaching and learning to teaching and learning in "virtual," or networked, environments. Networking learning resources, and learners, now makes it possible for us to provide seamless online learning environments, which can be used to support learning in any part of an organisation, anywhere in the world.

However, as we have seen, these new opportunities pose significant questions about the design of e-learning and about the development of understanding and skills required in offering courses in this way. A new paradigm is emerging for thinking about these issues, which is based on our understanding of the nature of knowledge and knowledge construction and which actively employs the unique characteristics of networked e-learning environments.

This is not a simple shift, but a complex cultural change. At the moment, it would seem that the emphasis is often on the technology rather than on how the technology can facilitate learning. Education and training sector personnel are being forced to make decisions about implementation while their knowledge and understanding of the learning potential of the new information and communication technologies is still emerging.

Why Do We Need Professional Development?

We are experiencing a paradigm shift in our thinking about learning. This is occurring at various levels. For example, there is a shift from conventional, second-generation distance learning toward virtual distance e-learning. Face-to-face teaching, learning, and training are now also incorporating some forms of networked e-learning, freeing staff and learners to work at times which personally suit them and to use resources and methods of working together that were not possible a few years ago. In the field of distance education and training, “distance” in learning is no longer the issue that it once was. The paradigm of networked collaborative e-learning shifts the emphasis from geographical separation of learners to the ways in which we can “network” learners together, whether they happen to be physically colocated or geographically dispersed, in the same country or situated anywhere in the world.

In a recent publication on collaborative e-learning in higher education, the need for staff development was clearly stated:

There are growing expectations of staff to offer more flexible forms of provision using technology, yet often with little or no training or support available (Lynch & Corry, 1998). To meet these expectations, there is a need for more staff development (Collis, 1998; McConnell, 1998; Wills, 1998) and staff development that caters to different levels of need (Crock & Andrews, 1997; Dearnley & Gatecliff, 1999; see also the proceedings of our Networked Learning Conference for other examples: Banks, Goodyear, Hodgson, & McConnell, 2002). The range of professional development needs is complex and goes well beyond technical skills to include pedagogical and managerial skills/knowledge. For instance, the provision of technology-mediated learning at an operational level indicates various professional development needs that include (Thompson, 1997):

- *conducting successful group discussions*
- *new class management techniques*

3. *Maintaining activity. The teacher/trainer maintains activity by:*

- netweaving — finding patterns and making connections in the work and communications of the community and reflecting this back to the community
- helping learners learn through discussion and social interaction
- ensuring there is a real meeting of minds and not just unassociated communications
- helping learners transfer existing learning metaphors to e-learning contexts
- showing “how” you communicate is as important as “what” you communicate, e.g., by personalising what you say. For example: face-to-face talk is highly personalised, asynchronous and synchronous textual communications is less personalised, and the written word is least personalised.

In working in networked collaborative e-learning contexts, teachers and trainers (and learners too) have to be given time to develop new skills which they can draw on to ensure they work together as harmoniously as possible (*Figure 2*).

Figure 2: Characteristics of Collaborative Teachers and Learners

<p>Characteristics of Collaborative Teachers <i>The collaborative teacher:</i></p> <ul style="list-style-type: none"> • helps to organise group • has good group development skills • consults • guides • is a resource provider • is an “expert” questioner • is a designer of learning experiences (not just content) • understands how to deal with asynchronous learning/discussion • reflects on their own practice • can see the learning potential of / tolerate / enjoy “chaos” at times • rarely lectures • has an “approachable” presence online • can communicate effectively via text - has “presence” online <p>Characteristics of Collaborative Learners <i>The collaborative learner:</i></p> <ul style="list-style-type: none"> • learns together through discussion, debate, questioning, problem solving, supporting each other • develops their own questions and searches for their own solutions • shares resources • shares the learning task • cooperates, and reciprocates cooperation • does not compete • has full and equal access to academic rewards (everyone can win) • understands the educational benefits of group/community work • understands that they can “construct” their own knowledge • tolerates multiple perspectives • enjoys diversity
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- *managing online commitments with other responsibilities*
- *developing appropriate assessment strategies*
- *changing administrative processes*

This places considerable responsibility on staff developers to provide appropriate forms of professional development that reflects the diversity of needs and different forms of possible provision. Indeed, the staff developers may also share the same professional development needs themselves (Isaacs, 1997) and there is therefore a need for “training the trainer” initiatives to address this problem (Alexander, 1999). (Banks, Lally, & McConnell, 2003, p. 30)

Learning how to work with the technology and take advantage of networked e-learning are the key issues to be addressed. Any teacher or trainer will have to develop skill and understanding of three important aspects of e-learning practice:

1. *Initiating activity. In initiating activity, the teacher/trainer:*
 - sets up discussion groups and workgroups in the virtual learning environment
 - invites participation
 - welcomes participants
 - helps set an agenda in consultation with participants
 - suggests a design for the environment

2. *Fostering group self-management. Fostering group self-management requires that the teacher/trainer:*
 - develops and maintains a supportive emotional learning climate
 - encourages the community to examine (by reflection) its own social processes
 - encourages members to talk, share, and debate with each other
 - encourages the setting up of protocols for using the medium (e.g., how often people might expect to be online; how they will communicate effectively)
 - shares responsibility for running and managing the group
 - creates a sense of ownership amongst participants
 - helps the community achieve its goals

The facilitation of Model Three networked e-learning is probably the biggest challenge that practitioners, and organisations promoting e-learning, are likely to face in the coming years. Although the production of e-learning material is by no means a simple achievement, it is probably, by comparison, a less complex process compared with the development of know-how about effective learning processes and skills required by e-learning facilitators. This is where our energy and time should be devoted in order to ensure e-learning becomes a quality experience and one that supports equality in learning (for example, see <http://tecfaseed.unige.ch/equel/equel.php> for details of a European project devoted to quality in e-learning).

Conclusions

The current interest in e-learning in many organisations is understandable: New information and communication technologies offer the potential of enhancing learning and training opportunities and of broadening the scope and availability of learning resources. They also promise to make training and learning more affordable and effective. However, e-learning practice is often still very traditional, with a focus on packaging resources as stand-alone learning material. This can have benefits in those training situations where well-known skills and information have to be passed on to learners, but as a method for knowledge development and sharing it has serious limitations.

Networked collaborative e-learning — where there is a premium on sharing of resources, knowledge, experience, and responsibility through reciprocal collaborative learning — offers an alternative method which has the prospect of helping learners in organisations work closely on shared problems and issues relating to their professional practice. I have argued in this chapter for this form of e-learning as I think it offers a true alternative to traditional forms of e-learning. Learners can collaborate on real-life problems and can share understandings and develop new insights into their practice that would otherwise not always be possible. Networked collaborative e-learning requires a change in our view of learning and a change in our view of our role as teacher or trainer. We have to view learners as able, self-managing people who can make decisions about their learning and who can learn in virtual social settings where the emphasis is on negotiation, collaboration, knowledge sharing, problem solving, and self-assessment. As practitioners in this new field, we have to view our role as being that of resource person, facilitator, critical observer, and co-expert. We have to be able to create learning designs that support new forms of learning and which sustain and develop learners in virtual learning contexts. This is quite a challenge but, as I hope I have shown here, it is well within our grasp.

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Introduction

For several decades, interorganizational information systems (IOS) have enabled the buyers and suppliers in a supply chain to exchange information electronically. By reducing the errors, costs, and time associated with the manual reentry of data, Electronic Data Interchange (EDI) technologies enable firms to reduce their transaction processing costs, cycle times, and inventory levels (Mukhopadhyay, Kekre, & Kalathur, 1995; O'Leary, 2000). However, the adoption of EDI systems limit trading partner flexibility, resulting in benefits often accruing to one partner at the expense of the other (H. G. Lee, Clark, & Tam, 1999). Furthermore, the usage of IOS has traditionally been limited to exchanging transactions rather than enabling the further benefits of supporting collaboration through the coordination of processes and information (Konsynski, 1996).

The recent innovations in more flexible Internet-based supply chain management information systems (SCM IS) promise to improve both the efficiency and agility of each of the partners in a supply chain (Green, 2001; Reddy, 2001a). Whether a firm implements an electronic marketplace, Internet EDI, extended enterprise resource planning (EERP) system, or other SCM IS, choosing the right approach is a risky undertaking given the number of factors that influence the total costs and benefits.

This chapter analyzes different types of SCM IS and presents a framework for understanding the expected costs and benefits of each type of IS. It begins with an overview of supply chain collaboration and its importance to many firms. It then describes the various SCM IS alternatives for supporting supply chain collaboration and introduces a framework for determining their expected costs and benefits. It concludes with an explanation of how firms can use the cost-benefit model to select and implement SCM IS that best fit their organization.

Supply Chain Collaboration

Collaboration is an approach to supply chain management (SCM) that moves beyond mere transactional exchanges to focus on joint planning, resource coordination, and process integration between buyers, suppliers, and other partners in a supply chain (Horvath, 2001; Kumar, 2001). Recent advances in electronic business practices are enabling firms to use collaborative commerce to drive out costs and increase return on assets in their supply chain, as well as increase their responsiveness to changing market demands (McLaren, Head, & Yuan, 2002). However, supply chain collaboration itself is not a new concept and

Chapter IX

Costs and Benefits in Supply Chain Collaboration¹

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Abstract

Recent advances in supply chain management information systems (SCM IS) have enabled firms to more fully collaborate with their supply chain partners — driving out costs while increasing responsiveness to market demands. This chapter examines various types of SCM IS — from traditional EDI systems to more recent Web-services-based e-business applications. It argues that the approach best suited for an organization depends in part on the degree of integration between the partners, the complexity of the business processes, and the number of partners involved. A model is presented for analyzing the costs and benefits that can be expected from each type of SCM IS. The model enables researchers and practitioners to better understand the differences among SCM IS and thus can help reduce the risks of implementing these valuable yet complex information systems.

has been used with varying success in SCM initiatives such as Quick Response (QR) or EDI (Borck, 2001).

Researchers differ on how strictly they use the term “supply chain collaboration.” Some emphasize that collaborative relationships are cooperative rather than adversarial or focused on price (Lamming, 1993). However, most business relationships are not fully collaborative and usually involve some imbalance of power that is wielded to the detriment of one of the partners (Bensaou, 1999). The presence of true collaboration often depends on who you are talking to — the buyer or the supplier! Other researchers use supply chain collaboration to refer to specific collaborative processes such as collaborative planning, forecasting, and replenishment (CPFR) or technologies such as electronic meeting rooms. However, like many practitioners, we prefer a more inclusive definition of supply chain collaboration as “*any type of joint, coordinated effort between two parties in a supply chain to achieve a common goal*” (McLaren, 2002).

Similarly, some authors have felt that the term supply chain has a connotation that is limited to supplier processes and does not emphasize the customer or distribution processes involved. Thus, we have terms such as value chains (Porter, 1985), supply networks (Harland, Lamming, Zheng, & Johnsen, 2001), and business webs (Tapscott, Ticoll, & Lowy, 2000) used interchangeably with supply chain, though their usage is not always consistent. However, in today’s demand-driven supply chains, the distinction between supply chains and demand chains is blurred and is dependent on perspective. In many cases, a web or network is a more accurate metaphor than a chain, though the distinction is not important to this paper, as collaboration still mainly occurs between only two partners at one time. Again, we use supply chain as it is most commonly used to include all the partners involved in delivering a good or service to a customer.

Businesses in the early part of the 20th century were often characterized as vertically integrated operations. Integrated operations like Ford Motor Company performed manufacturing, sourcing, warehousing, sales, and logistics functions “in-house.” However, by the late 1900s, vertical integration had substantially disappeared and most organizations included external partners in their supply chain. Since these external partners (suppliers, transportation providers, retailers, etc.) are outside of the management control of an organization, supply chain management has traditionally involved each organization managing their portion of the supply chain and monitoring their partners to ensure they fulfill their contractual obligations (Ballou, 1999).

There can be numerous problems with this approach, the best known perhaps being the “bullwhip effect” (see *Figure 1*), where the effects of uncertainty in demand and lead times cause order sizes and lead times to be inflated the further up the supply chain and away from the end customer the orders for suppliers get.

This leads to a greater amount of excess and often obsolete inventory throughout the supply chain, as extra inventory is required to protect against uncertainty and stock outs between each link in the chain. However, with increased management coordination of the supply chain and by making end-customer demand information readily available to the entire supply chain, the demand uncertainty along the chain and its resulting bullwhip effect can be reduced (H. L. Lee, Padmanabhan, & Whang, 1997b).

While supply chain management focuses on controlling the activities among the supply chain partners, supply chain integration focuses on improving the information flow between links in the chain, and supply chain optimization or coordination focuses on making decisions that reduce the information asymmetry and resulting excess inventory in the supply chain. If only the dominant partner drives supply chain optimization decisions, this can create an asymmetrical distribution of information, inventory, and ultimately bargaining power between the partners (Iacovou, Benbasat, & Dexter, 1995). In order to optimize the entire supply network instead of creating local optima in one or two partners, the organizations must make *joint* supply and demand decisions that create sustainable value for all involved. Hence, many organizations are increasingly developing strategic partnerships with their suppliers and customers and implementing supply chain collaboration initiatives in an effort to reduce waste in their procurement and order fulfillment processes (Porter, 1985).

As shown in *Figure 2*, operational-level applications of supply chain collaboration principles focus on exchanging and integrating information between partners using interorganizational information sharing techniques such as EDI or extended ERP as well as transaction cost reduction programs such as vendor-managed inventory (VMI). At the tactical level, programs such as collaborative planning, forecasting, and replenishment (CPFR), continuous replenishment (CRP), and sharing of point-of-sale (POS) demand information move beyond a focus on transactional efficiency and attempt to achieve further top and bottom

Figure 1. Information Distortion: The Bullwhip Effect

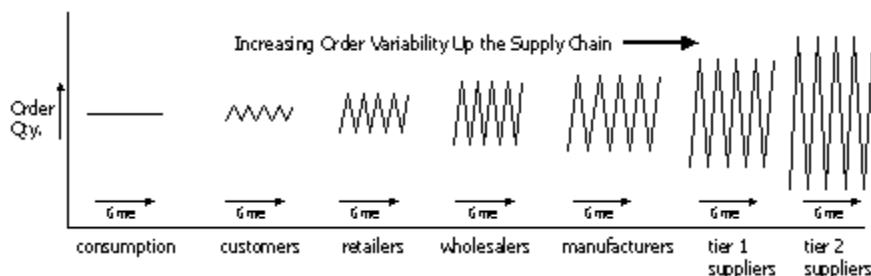
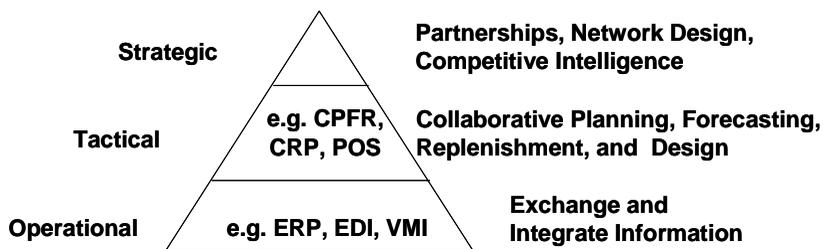


Figure 2. Example Supply Chain Collaboration Initiatives



line benefits through coordinating supply and demand (Barratt & Oliveira, 2001). Finally, strategic-level applications of supply chain collaboration involve the decisions about partnerships, network design, and gathering competitive intelligence in order to support such strategic decisions.

The common feature of every supply chain collaboration initiative is that it (ideally) involves the coordination of trading partner goals, decisions, processes, and performance management to achieve some shared benefit (Moncrieff & Stonich, 2001; Quinn, 1999). Effective supply chain coordination can eliminate excess inventory, reduce lead times, increase sales, and improve customer service (Anderson & Lee, 1999). Using some variation of EDI to exchange purchasing transactions electronically results in more timely and accurate orders with lower transaction costs (Mukhopadhyay et al., 1995; Seidmann & Sundararajan, 1998). Partners can then deliver products “just-in-time” without having to maintain costly inventory buffers “just-in-case.”

However, merely exchanging transactions among trading partners more quickly and cheaply is no longer enough to maintain a competitive advantage for many firms. Instead, supply chain partners like retailer Wal-Mart and manufacturer Proctor & Gamble use more collaborative initiatives such as CPFR to better synchronize supply and demand, coordinate marketing efforts, and further eliminate waste in the supply chain (Koch, 2002). By jointly sharing supply and demand plans in addition to transactions, firms can further reduce the bullwhip effect while increasing their responsiveness to market demands and customer service (Mentzer, Foggin, & Golicic, 2000).

Furthermore, while operational-level inter-enterprise systems such as EDI systems often benefit customers much more than suppliers (H. G. Lee et al., 1999), systems that support tactical and strategic collaborative planning help ensure that the benefits of coordination are sustainable and experienced by all members of the chain, not just the customers. This shared value enhances the

sustainability of the relationship, while equalizing the bargaining power of the partners (Seidmann & Sundararajan, 1998) and strengthening their level of trust (Karahannas & Jones, 1999).

In summary, the benefits of supply chain collaboration can include not only the reduction of waste in the supply chain, but also increased responsiveness, customer satisfaction, and competitiveness among all members of the partnership as the firm focuses on tactical and strategic applications of the principles (Mentzer et al., 2000). To support supply chain collaboration, IOS are required to handle the large volume of information that must be shared between the partners and to facilitate the coordination and management of the supply chain processes involved. In the following section, we describe the various SCM IS alternatives and introduce a framework for determining their expected costs and benefits.

Classifying Supply Chain Management Information Systems

There are many different types of supply chain IOS, such as EDI- or inter-enterprise application integration (IEAI)-based systems, electronic marketplaces, or even noncomputerized phone- or fax-based systems. Unfortunately, there are often confusion and inconsistencies among the terms used to classify a particular type of SCM IS. For example, for what Kaplan and Sawhney (2000) call an “e-hub,” others use the terms “online public trading exchange” or “third-party electronic marketplace.” To others, an e-hub is something different — an internal software platform for providing connectivity to trading partners (Stevens, 2001), something some researchers call a “portal” (Reddy, 2001b). Similarly, using the term “portal” can lead to confusion unless one specifies whether it is a customer portal, supplier portal, or internal (corporate) portal and more importantly what capabilities it provides.

Adding to the confusion is the considerable overlap in the technologies used and capabilities provided by each type of SCM IS. Many firms adopt a portfolio of information and communication technologies (ICTs) for supporting their supply chain, which frequently contains a mix of EDI, ERP, and procurement solutions. It is difficult to classify such hybrid systems as strictly one type or another (Dagenais & Gautschi, 2002). Nonetheless, we have tried to adopt the most widely used terms used in practice in describing SCM IS and will explain their key differences in the following.

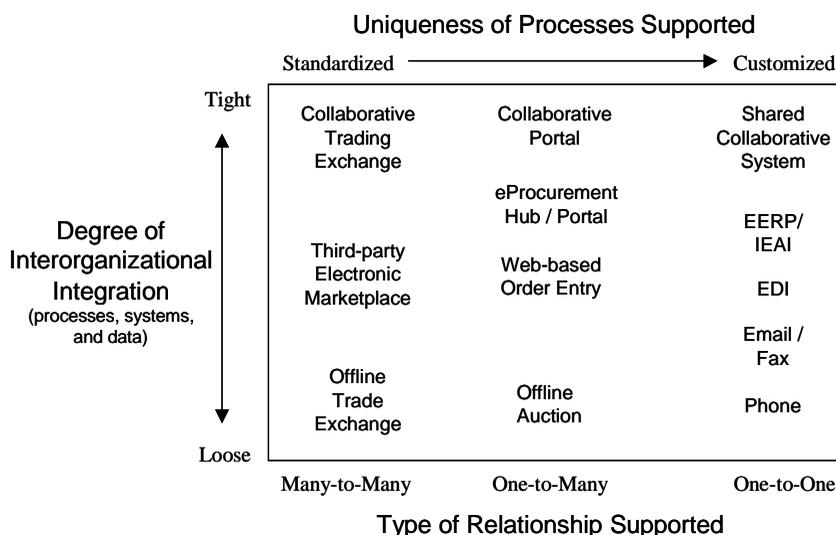
SCM IS have varying capabilities for coordinating supply and demand informa-

tion throughout a supply chain, which can reduce the bullwhip effect (H. L. Lee, Padmanabhan, & Whang, 1997a; van Hoek, 2001) and enable the benefits of more collaborative supply chain management (Horvath, 2001; Kumar, 2001; Peterson, 1999). One way of differentiating SCM IS is by looking at how information is coordinated between the supply chain partners. This can be accomplished through: sending messages from one firm's computers to another; interacting with another firm's computers; or through using a shared IOS that contains both firms' information. This distinction allows us to classify SCM IS roughly as:

- *message-based* systems that transmit information to partner applications using technologies such as fax, e-mail, EDI, or Extensible Markup Language (XML) messages;
- *electronic procurement* hubs, portals, or marketplaces that facilitate purchasing of goods or services from electronic catalogues, tenders, or auctions; and
- *shared collaborative* systems that include collaborative planning, forecasting, and replenishment capabilities in addition to electronic procurement functionality.

However, since there are still major differences between different types of SCM IS within each of these groupings, we describe further ways of distinguishing between them. Other key differences between SCM IS are the type of trading relationships and processes they are designed for and the degree of interorganizational integration they support, as shown in *Figure 3*. An important attribute of the IS is the cardinality of the interorganizational relationships the system is designed to support (McLaren et al., 2002). In other words, is the system optimized for supporting one-to-one relationships, such as EDI, or many-to-many relationships, such as multiple suppliers and customers interacting in an electronic marketplace? Somewhere in between these extremes lie systems designed for one-to-many relationships such as Web-based order entry systems or auctions. This is not to say that EDI systems cannot be used to interact with dozens of suppliers and customers. Instead, each additional EDI customer-supplier link requires a significant effort to integrate the systems, processes, and data definitions between the two partners, resulting in multiple one-to-one relationships with all of the EDI trading partners. In contrast, once an organization integrates its systems with an electronic marketplace, it can engage in multiple trading relationships with minimal incremental effort (Bakos, 1997).

Figure 3. Information and Communication Technologies for Supply Chain Management (after McLaren et al., 2002)



Similarly, the capability of the systems to support unique or customized supply chain processes between the trading partners coincides with the type of relationship for which the system is designed. Since electronic marketplaces are designed for many-to-many supplier-to-customer relationships, they require a high degree of standardization of business processes. In contrast, since systems using EDI or IEAI involve linkages between one customer and one supplier at a time, they can support much more customized and unique business processes.

The other key variable that distinguishes SCM IS is the degree of integration achieved or required between the partners. Tight integration implies a close alignment of the trading processes, systems, and data definitions between the partners and communication that allows information to flow efficiently between the organizations. In contrast, loosely integrated trading partners have significant differences in business processes and data definitions that require substantial human intervention to pass information between the two organizations. Even though EDI achieves tight data integration, it often fails to facilitate the harmonization of business processes and systems amongst the trading partners. By comparison, IEAI usually results in closer alignment of business processes and systems as partners are forced to agree upon a process or use the process models embedded in the enterprise systems. Similarly, when joining an electronic marketplace, companies must align their processes and data definitions with the standards enforced by the marketplace.

Expected Benefits and Costs of SCM IS

Based on a review of previous studies, the following section presents a framework for understanding the net benefits that can be expected from various types of SCM IS. While the expected benefits have been published widely, there has been little focus on the costs of choosing a specific type of SCM IS. However, as can be seen in the inability of many SCM IS to live up to expectations, failure to account for intangible costs, such as the opportunity cost of inflexible IS, can be very risky.

Typical Benefits

Supply chain collaboration initiatives focus on reducing uncertainty in the supply chain, which can lessen the bullwhip effect and lead to lower inventory costs and faster time-to-market (H. L. Lee et al., 1997b). Collaborative partnerships also lead to increased economies of scale and risk sharing (Kumar & van Dissel, 1996). While quantifying these benefits is challenging, several surveys and studies have concluded that the expected benefits of supply chain coordination and collaboration fall into the categories of cost reduction and increased responsiveness (Chopra & Meindl, 2001; Fogarty, 2001; Industry Directions Inc. & Syncra Systems Inc., 2000; Mentzer et al., 2000; Supply-Chain Council Inc., 2002).

Cost reduction benefits include reduced inventory, process costs, and product costs that result from the coordination of actual customer demand with supplier production plans. Effective supply chain coordination can eliminate excess inventory, reduce lead times, increase sales, and improve customer service (Anderson & Lee, 1999).

In addition, collaboration has resulted in faster product-to-market cycle times, improved service levels (based on stock outs, lead times, and quality), and a better understanding of end-customer needs throughout the entire chain through market intelligence and demand visibility (Mentzer et al., 2000). However, the level of benefits achievable through collaboration is influenced by a number of factors that have not been well investigated, such as how well the systems support the efficiency and flexibility requirements of the supply chain (Reddy, 2001a; McLaren, 2004) or the level of trust between the trading partners (Karahannas & Jones, 1999). Furthermore, while several studies attest to the transaction cost savings of interorganizational systems (Mukhopadhyay et al., 1995; Seidmann & Sundararajan, 1998), they often ignore hidden costs such as maintenance or errors or the opportunity costs of not being able to trade with other partners due to an inflexible SCM IS.

Typical Costs

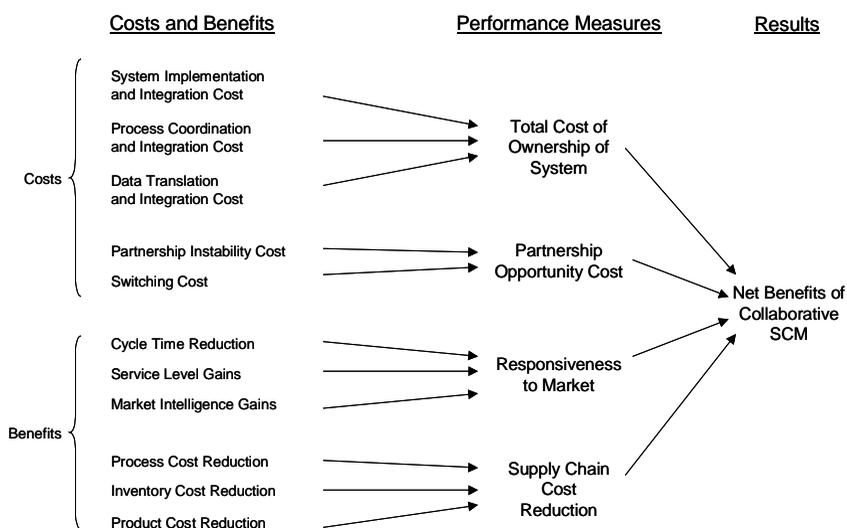
Typical costs of SCM IS include total cost of ownership (TCO) and partnership opportunity cost. TCO includes the total life-cycle costs of the chosen processes and systems, including cost of systems acquisition, usage, maintenance, dealing with errors and inefficiencies, and integration with partners over the lifetime of the system (Degraeve & Roodhooft, 1999).

The partnership opportunity cost is the benefits that are foregone due to using a SCM IS that limits a firm's ability to trade with different partners. The partnership opportunity cost includes the costs of switching partners and costs of partnership instability, both of which are related to the transaction costs involved in searching, contracting, and establishing linkages with trading partners. For example, inflexible systems based on Electronic Data Interchange (EDI) have high costs for switching to other partners, which results in reduced supply chain agility. This is because the inflexibility of the EDI system often precludes the organization from entering into relationships with other partners that could have been of a higher value to the organization (Poirier & Bauer, 2001). In addition, highly flexible systems that do not promote long-term relationships (such as many auction-based systems) will result in instable relationships. This instability results in the partners foregoing the benefits of long-term collaboration, resulting in further partnership opportunity costs, even though the switching costs in auctions are low (Anderson & Lee, 1999). Therefore, a high partnership opportunity cost can result from either high switching costs or high partnership instability, or both.

It is important to note that in supply chain collaboration, low switching costs are desirable. At first, this may seem contrary to Porter's (1985) assertion that high switching costs are desirable for preventing customers from trading with other partners. However, as we have discussed, low costs of switching partners enables organizations to more easily support the relationships that are the most beneficial to the organization and thus lower the opportunity cost associated with a partnership. Indeed, several studies have suggested that partnerships that are maintained through coercion, threats, or high switching costs fail to provide the equity of benefits to both parties that are required for sustainable collaboration (Iacovou et al., 1995; Kumar & van Dissel, 1996).

Thus, *Figure 4* shows how supply chain collaboration benefits fall into two broad categories: enhanced responsiveness to market demands and reduced supply chain costs (Mentzer et al., 2000). The costs involved in SCM IS fall into two broad categories: the total cost of ownership of the IS (Degraeve & Roodhooft, 1999) and the partnership opportunity cost — the cost associated with being tied into a specific partner (Poirier & Bauer, 2001).

Figure 4. Costs and Benefits of SCM IS (McLaren et al., 2002, used with permission)



In the following subsections, we further describe and analyze the types of SCM IS available for supporting supply chain management and coordination. To highlight the capabilities of more sophisticated computer-based SCM IS, we begin with a brief description of the traditional less-automated approaches. Following a brief description of each type of SCM IS, we outline the expected costs and benefits of each.

Phone/Fax/E-Mail Systems

Traditionally, many supply chain activities have involved the usage of manual and semi-automated phone, fax, and e-mail systems in addition to face-to-face and paper-based transactions. For many functions such as establishing relationships and initial contract negotiations, these methods are indispensable and unlikely to be replaced completely by more automated systems. However, many supply chain processes can be made much more efficient by employing information technology to improve information sharing, reduce errors and rework, and free resources to work on more value-added tasks (O’Leary, 2000).

Phone, fax, and e-mail systems all support highly flexible and customized trading relationships, though they lack standards in their usage. They are very suited for

communicating unstructured information but do not support communicating structured information into the recipients' systems electronically. As a result, they do not support a very tight degree of interorganizational integration. While e-mail systems can transmit structured information such as electronic purchase orders directly into a recipient's system, we classify that type of system as EDI. In our classification, we assume that phone, fax, and e-mail messages contain unstructured text or images.

The net benefits accrued from information sharing using phone, fax, and e-mail systems are limited mainly by the fact that the information communicated is difficult to integrate into the receiver's systems without manual processing and data translation.

Offline Auctions/Trade Exchanges

Offline auctions involve one supplier and many customers (in a forward auction) or one customer and many suppliers (in a reverse auction). As the auction process usually focuses on price as the prime decision variable, they have had the widest acceptance in commodity markets. Offline trade exchanges help coordinate similar markets, yet are designed to support many-to-many relationships. Both offline auctions and trade exchanges support only a limited degree of interorganizational integration, as the systems and data are not electronically integrated, and the business processes amongst the trading partners are often disparate and uncoordinated.

Offline auctions and exchanges may yield benefits to a supply chain in increased market efficiency and reduced searching costs, which result in a moderate product and process cost reduction. However, as the information exchanged is typically not integrated with any systems, there is minimal benefit in terms of increased responsiveness of the supply chain or reduction of inventory. As a result, many former offline auctions and exchanges have migrated to online electronic marketplaces (such as the General Electric Trading Exchange) to increase the benefits of integration and coordination amongst their members.

Electronic Data Interchange (EDI)

The traditional method for businesses to exchange operational information electronically has been through sending messages from one computer to another — a process known loosely as Electronic Data Interchange (EDI). Numerous studies have shown that EDI can reduce transaction-processing costs to near negligible levels (Mukhopadhyay et al., 1995; O'Leary, 2000). However, the

total cost of ownership of EDI systems is substantial due to the systems and data integration efforts required. Furthermore, this integration effort usually requires a large amount of “hard-coded” data translations, which results in a system that is less flexible in adapting to changing partners, processes, and data structures (Konsynski, 1996).

Two opposing standards that define the format for EDI messages have gained wide usage, although other companies such as Wal-Mart use proprietary formats (Macht, 1995). The ANSI ASC X.12 standard is widely used in North America and the United Nations-backed EDIFACT standard is more common elsewhere in the world. While EDI provides definitions for common message formats to be exchanged, its rigid data model and inflexible formatting requirements force trading partners to expend considerable effort in formatting the data and agreeing upon a common data model (Mukhopadhyay et al., 1995). Furthermore, EDI systems are proprietary, complex, and costly and often require smaller partners to be coerced into implementing them (Archer & Gebauer, 2000; H. G. Lee et al., 1999). The result is that EDI relationships usually cannot be implemented easily, quickly, or inexpensively (Moore, 2001). This is because EDI standards focus more on defining the rigid message structure and less on defining which data fields are required for a transaction and how the information should be interpreted.

Thus, two trading partners wishing to exchange EDI messages need to first agree upon how to structure and interpret messages and then must configure their systems to translate their legacy data into this common format. If one partner then wanted to exchange EDI messages with a third organization, it would need to start the negotiations all over again with that party in order to adopt a common data model (Moore, 2001). As each party would like to use their own data model and minimize the data translation required, the likely outcome is that organizations would need to translate their data separately for each of their trading partners rather than being able to use one common model. The result is high system and data integration costs. On the positive side, since EDI participants must adhere to common standards, the costs of coordinating their processes are lower than most of the alternatives.

Since most organizations are incapable or unwilling to support EDI transactions with numerous diverse partners, EDI trading networks often follow a hub-and-spoke architecture centred on the dominant customer rather than a web-like network. For example, in the retail sector, Wal-Mart has had sufficient influence with its suppliers to mandate the use of proprietary formatted EDI messages in order to do business with Wal-Mart (Macht, 1995). This arrangement creates a barrier to entry for Wal-Mart competitors, as it makes it less likely that the suppliers will adopt different EDI message formats for smaller customers who have a different data structure than Wal-Mart.

fields is still critical. While XML is more flexible in dealing with structured data transactions, like traditional EDI, it still requires adoptions of common standards for exchanging business documents. However, unlike EDI, XML provides a facility to interpret and validate documents against an electronic version of these standards (often called schema). Hence, it is easier for trading partners to develop and maintain their own flexible standards, whereas changes to the EDI standards require all parties to update their software or manually agree upon which versions they will support, which is much more cumbersome.

Compared to traditional EDI, IEAI or EDI using XML provides a more efficient means of sharing structured data between organizations (Glushko, Tenenbaum, & Meltzer, 1999). However, one can imagine that there is little benefit to each organization using their own XML schema. Instead, some industry groups and software vendors have banded together to try to establish their own XML vocabularies and schema repositories. Examples of these include FinXML and FpML for finance; ebXML, cXML, OTP, and PDML for general e-commerce; SAEJ2008 for the automotive industry; RNIF for the electronics industry; and many more. Again, one can see that “standards” often are not standard, and “interoperability” usually has very narrow applicability. Even in single industries, there are competing XML vocabularies, often spearheaded by competing companies or solution providers seeking industry dominance (McLaren, 2001).

Web-Based Order Entry Systems

Web-based order entry systems, sometimes referred to as business-to-consumer (B2C) or business-to-business (B2B) Web sites or customer portals, enable customers to interact directly with a supplier’s sales order system. As opposed to eProcurement applications, Web-based order entry systems reside on the supplier’s computers. Since the customer manually enters the information, the degree of systems and data integration between the customer and supplier is loose, even though the supplier’s systems may be internally integrated. Furthermore, since the customer must conform to the supplier’s business processes, the degree of process integration or coordination between the two parties is also loose. Note that if transactions are predominately communicated electronically rather than entered manually, we classify those systems as EDI or IEAI systems, which are discussed in the preceding sections.

With Web-based order entry systems, the information exchanged between the customer and supplier is consistent with the supplier’s system, resulting in a lower error rate and minimal rework of the information, as compared to voice- or paper-based transactions. However, while the supplier does not need to translate the information (as it is already entered into their system), the customer

While Wal-Mart currently enjoys the purchasing power to mandate such usage of EDI with its suppliers, it is an adversarial strategy that few customers can afford to maintain. Even for Wal-Mart, once more flexible collaboration alternatives become available to its suppliers, they will be forced to reconsider this strategy. In general, the inflexibility of the EDI hub-and-spoke model has disadvantages to both suppliers and customers, as it makes it costly to share information electronically with alternative trading partners.

Inter-Enterprise Application Integration/Extended ERP

Inter-enterprise application integration (IEAI), sometimes known as “Web services,” is also a standards-based messaging approach to integrating systems similar to EDI. However, it usually implies the use of XML-formatted messages and integrated enterprise-wide systems rather than rigid EDI formats and disparate legacy systems. IEAI in a supply chain usually involves one-to-one integration between enterprise applications, including legacy systems, ERP, SCM, or advanced planning and scheduling (APS) systems.

Extended ERP (EERP or ERP II) involves the sharing of information electronically between two ERP systems and can be done using industry-standard or proprietary EDI or XML formats. However, it increasingly uses open XML formats rather than traditional EDI messaging. Since EERP is a type of IEAI, we will not distinguish between the two further.

In contrast to the “send-and-receive” approach of EDI, IEAI often uses a “publish-and-subscribe” approach to achieve the same benefits of electronic information exchange in a more flexible manner using the Internet and Extensible Markup Language (XML) message formats. However, the distinctions between EDI, IEAI, and XML Web services approaches are often blurred, as there is frequently a mix of proprietary and standards-based approaches used.

The usage of data tagged in XML formats enables different organizations to view the same shared data in the format they prefer. As long as two organizations agree upon the meaning of a piece of data, they may use different XML “schemas” to present the information differently to their users. For example, if one organization calls a quantity of product “a skid of soda” and the other calls it a “pallet of pop,” they must standardize the unit of measure in the database but then could use different XML schemas to translate that unit of measure back to the preferred terminology in their own systems (Marron, 2001).

The prime benefit in using XML for EDI or IEAI is that it allows data fields in business documents to be identified using XML tags, rather than requiring rigid file layouts, as in traditional EDI. Though the location of the data in the document is no longer important, a shared understanding of the meaning and usage of those

electronic procurement system. A “supplier portal” or “hub” usually refers to a Web site belonging to an organization that allows its suppliers to integrate their systems and processes with those of the organization (Stevens, 2001). In this chapter, we will refer to each of these types of systems as electronic procurement portals. In contrast, a “customer portal” is another term for a Web-based order entry system, which was discussed in the preceding section.

An example of a supplier portal is one created by automotive manufacturer Volkswagen Group (VW). The VWGroupSupply.com portal provides access to VW’s procurement and planning systems for their suppliers. Upon implementing this portal for their suppliers, Volkswagen Group has reported a 95% reduction in business process times, improved planning accuracy, and reduced inventory levels (Waheed, 2001).

Electronic procurement systems increase the efficiency of trading partners by integrating the data, processes, and systems utilized in a supply chain. They can lead to lower product prices through spending consolidation and process efficiencies (Archer & Yuan, 2000). However, the biggest savings come from ensuring purchasing compliance by reducing off-contract buying and forcing purchases to be made against established contracts (Hope-Ross, Lett, Luebbers, & Reilly, 2000).

The benefits of electronic procurement solutions come at a cost of the integration and translation efforts required to facilitate electronic transactions among the partners (Archer & Gebauer, 2000). Although they can result in lower transaction costs, the cost of maintaining different electronic catalogues for different customers and from integrating these into another organization’s systems can be high (Ginsburg, Gebauer, & Segev, 1999).

However, as integrating and aggregating information between applications in a supply chain using portal technology can be done incrementally and often quite cheaply, the payback period is usually much shorter than large-scale supply chain integration projects involving enterprise application integration (Reddy, 2001b). Furthermore, since large supply chain integration projects may span several companies and functional areas, it is difficult to measure return on investment (ROI) and thus the projects are hard to justify in times of economic uncertainty. In summary, portals for supply chain collaboration allow quick wins by facilitating information sharing and increasing the usability of disparate systems.

Electronic Marketplaces/Trading Exchanges

Electronic marketplaces or trading exchanges “are online business-to-business (B2B) community groups that link participants to a global network of buyers and sellers” (Stevens, 2001, p. 30). They can include public marketplaces hosted by

is required to do a mental translation of their processes and information into the process and format required by the supplier's order entry system. Thus, the supplier experiences efficiency gains from the integration, while the customer experiences fewer such benefits, especially after having to learn how to interact with several different supplier Web sites.

These systems are also designed primarily for transactional information processing, rather than tactical or strategic supply chain collaboration. For example, most Web-based order entry systems do not make tactical information such as actual product availability or lead times available, which would provide more of a benefit to their customers. In a system that benefits the supplier much more than the customer, the efficiency gains of integration are self-limiting because the customers have low switching costs and will tend to seek out relationships that are more desirable. As a result, organizations participating in supply chains primarily dependent on Web-based order entry systems will experience only a moderate level of cycle time reduction, service level gains, and market intelligence gains due to the partial integration of information (McLaren et al., 2002). Note that if strategic planning information were made available to the customers on the Web site, such as "available-to-promise" data, then the collaboration gains would increase. However, again, the lack of integration with the customer's systems and processes would limit the benefits realized. If the information were integrated with the customer systems, then the system would be better termed a hub or portal, as described in the following section.

Electronic Procurement Hub/Portal

Systems that support electronic procurement of goods or services typically take the form of customer or supplier portals, hubs, marketplaces, or trading exchanges. There are usually architectural differences behind each of these terms; however, the terms are often used interchangeably and their distinction is not terribly important to this discussion of ICTs. In general, electronic procurement systems, hubs, or portals focus on facilitating electronic catalogue-based orders from select supplier partners, whereas electronic marketplaces (which are discussed in the next section) are geared towards competitive sourcing and auction mechanisms.

Procurement hubs or portals are typically Web-enabled SCM IS that allow an organization to electronically integrate its systems and processes with those of its trading partners. An "electronic procurement portal" usually includes electronic supplier catalogues and functionality to submit purchase orders electronically to suppliers from within the portal application. Typically, the customer performs most of the effort of integrating the supplier catalogues into the

a third party or private trading exchanges hosted by a supply chain participant. They usually include capabilities for product sourcing and ordering such as electronic catalogues, online auctions, and sometimes approvals routing and contract management (Archer & Gebauer, 2000). Public trading exchanges can be hosted by individual distributors (such as W.W. Grainger for indirect materials), consortiums (such as Covisint for automobile manufacturers), or third-party market makers (such as CommerceOne, Chemdex, or eSteel; Dagenais & Gautschi, 2002; Kaplan & Sawhney, 2000). However, because of factors such as trust and market liquidity (attracting enough participants and transactions), private trading exchanges have typically been more successful than public trading exchanges (Dagenais & Gautschi).

Like EDI, electronic marketplaces have proven useful for integrating supply chains for some organizations but have not been as widely accepted as had been predicted. There are several obstacles to participating fruitfully in an electronic marketplace, including supplier resistance, buyer resistance, connectivity, and return on investment (ROI) issues (Dagenais & Gautschi, 2002; Stevens, 2001). Initially, suppliers have been reluctant to join electronic marketplaces as the highly competitive auction process usually involved has to date been focused primarily on achieving unsustainably low prices. Price-focused auctions commoditize the goods or services sold and drive suppliers who are unwilling to further reduce their margins to seek alternative trading relationships in which they can compete on non-price terms, such as quality and service levels (White, 2000).

In order to gain more acceptance with suppliers, electronic marketplaces will need to facilitate negotiations on other terms, such as quality, service level, and payment terms, and support longer-term contracts. Otherwise, many suppliers will continue to focus more on building less flexible one-to-one connectivity with their strategic partners (Stevens, 2001).

Likewise, buyers are hesitant to join marketplaces that do not support the robust types of negotiations that are required for long-term successful relationships. They also have legitimate concerns about having their supply chain transactions and planning forecasts so easily visible to their competitors in the marketplace. Furthermore, buyers in industry-specific marketplaces, such as Covisint, have found it difficult to come to agreement with their business rivals upon the required infrastructure, processes, and standards required to support the transactions.

Ultimately, despite low infrastructure costs of the Internet and the emergence of promising technologies such as XML, the present state of B2B connectivity has not progressed far beyond the rigid standards of EDI. While the Internet has reduced the cost of bandwidth, most trading situations still require significant investment to translate legacy data into some format agreed upon by the marketplace participants (Ginsburg et al., 1999). Since there is presently no

agreed-upon standard that is sufficiently flexible to accommodate all trading partners, organizations must expend a significant amount of resources to set up those linkages to the marketplace and other partners they need to interact with. In many cases, it has been impossible to meet the payback period requirements of less than a year, which has become the minimum criteria for many IS projects (Stevens, 2001).

The result has been that few electronic marketplaces have achieved the trading volumes that were originally budgeted for and many have been dissolved within years of their launch (Dagenais & Gautschi, 2002; Stevens, 2001). Nonetheless, as technology and standards evolve, electronic marketplaces hold considerable promise for reducing transaction costs and enabling tighter collaboration throughout the supply chain.

Shared Collaborative SCM IS

The preceding IOS are all similar in their approach of facilitating collaboration through system integration. In contrast, the use of shared or jointly owned collaborative systems takes a different approach that eliminates much of the integration and translation efforts but instead focuses upon reaching mutual agreement upon a shared process and system. These systems could include jointly owned dedicated supply chain management systems or could include the conventional planning, forecasting, and product design modules from ERP or APS systems, such as SAP or i2, which have been made accessible for partner access. More recently, software vendors such as Logility and Syncra Systems have created add-on or stand-alone packages that provide even greater collaboration capabilities, such as data transformation, planning calendar synchronization, and flexible views of the information for supporting the different needs of the partners (Peterson, 1999). It is anticipated that these advanced collaboration capabilities will be incorporated into the next generation of ERP and APS software.

Shared collaborative SCM IS go beyond mere sharing of operational data such as production schedules and available-to-promise capabilities. They also facilitate exchange and coordination of tactical information such as supply and demand forecasts and may even assist strategic planning through trade network design and optimization (Kumar, 2001).

Through their support of joint planning initiatives such as CPFR, shared collaborative SCM IS can greatly reduce the bullwhip effect and yield more accurate demand forecasts (Barratt & Oliveira, 2001). Both the supplier and customer jointly agree upon supply and demand forecasts and plans and can coordinate their promotion and distribution strategies. The result is more predictable

demand, which lessens the amount of inventory required in the supply chain and reduces the amount of exception processing and expediting required, leading to cycle time reduction and service level gains (Anderson & Lee, 1999; Mentzer et al., 2000). Furthermore, the joint collaboration allows a high level of market intelligence to be shared throughout the supply chain, as customers, distributors, and suppliers can all share information about customer needs (Anderson & Lee).

The process coordination costs involved with shared collaborative SCM IS are high, as each partner must adapt their own unique business processes to the jointly coordinated process. Similarly, both parties must agree upon a mutual data format and must translate and integrate the shared data with their own systems, resulting in a high data translation and integration cost. However, since the shared system acts like a single hub, the system integration costs are not expected to be as high as in many point-to-point EDI or IEAI solutions. The system interface costs are a function of the number of partners that need a different system interface, and therefore the centralized or shared systems are expected to have lower system integration costs than the point-to-point solutions (Ginsburg, 1999).

Furthermore, since two or more partners invest in the shared system, the cost of switching partners is high. Although this limits flexibility, since the shared collaborative SCM IS usually have large benefits for both the customers and the suppliers in a trading relationship (Anderson & Lee, 1999), the relationships are often more sustainable and the costs of partnership instability are lower.

Using the Cost-Benefit Model to Select SCM IS

This section explains how researchers and practitioners can use the cost-benefit model along with other decision criteria to select SCM IS that best fit their organization.

As was shown in *Figure 4*, the net benefits of SCM IS are derived from the total costs of ownership, the opportunity costs due to inflexibility, the enhanced market responsiveness, and the amount of supply chain cost reduction. In general, the lowest cost alternatives can be expected to yield the least amount of benefit from collaboration (McLaren et al., 2002). Similarly, the SCM IS offering the high potential benefits of collaboration have higher costs of ownership and opportunity costs. The exception is EDI systems, which tend to have high opportunity costs due to their inflexibility and a high total cost of ownership due to high ongoing system and data integration costs (Moore, 2001). *Figure 5* shows a generalized relationship between overall costs and benefits for different types of SCM IS.

Since costs generally increase with benefits, then the decision of which type of SCM IS to deploy often comes down to the question of how tightly does the firm need to be integrated with its partners in order to achieve the desired degree of supply chain collaboration. In other words, the type of IOS that should be deployed depends primarily on the level of interdependence of the partners (Kumar & van Dissel, 1996).

There are three levels of interdependence of trading partners (Robey & Sales, 1994; Thompson, 1967). The first level of interdependence is “pooled dependency,” whereby firms are independent but must share a common resource. A SCM IS example might be an electronic marketplace that gives participants access to a database of qualified suppliers and their product catalogues. The second level is “sequential dependency,” where the output of a process becomes the input of a process in another firm. A SCM IS example might be an EDI-based system for sending and receiving purchase orders between two established partners. The third level of interdependency is “reciprocal dependency,” wherein inputs and outputs flow recursively between the organizations. A SCM IS example is a collaborative portal used by Wal-Mart to support joint planning, forecasting, and replenishment activities with their key suppliers (Dagenais & Gautschi, 2002).

A higher degree of interdependence can reduce the bullwhip effect and lead to better-optimized supply chains (H. L. Lee et al., 1997a). However, as the level of interdependence of organizations increases, so does the potential for conflict, the impact of failed relationships, and the resulting risk. While higher interdependency can lead to many collaborative benefits, the information systems and coordinating mechanisms become more important and must rely less on rules and standards and more on joint planning, mutual adjustment, and trust (Kumar & van Dissel, 1996).

Thus, organizations need to consider a number of factors when selecting SCM IS. The number of trading partners involved and degree of interorganizational integration or interdependence with each dictate whether SCM IS should be chosen that are optimized to support one-to-one, one-to-many, or many-to-many trading partner relationships. Similarly, how standardized or customized the trading processes are will also dictate the type of SCM IS, as shown in *Figure 3*. However, since this is only a rough guideline, firms should analyze the expected costs and benefits of each option using the model shown in *Figure 4*. It is critical that cost-benefit analyses include not just the cost of implementing the SCM IS, but also the ongoing costs of systems, process, and data integration as well as the opportunity costs of trading partner inflexibility.

Conclusions

Supply chain management information systems (SCM IS) have become important tools for supporting collaborative commerce among the customers and suppliers of a supply chain. However, the rate of innovation in information and communication technologies for supporting supply chain collaboration has made the selection of SCM IS a difficult and risk-prone decision.

The benefits of using SCM IS to support supply chain collaboration have been clearly demonstrated by several large and powerful companies, such as Dell Computers, Wal-Mart, and Cisco Systems (Dagenais & Gautschi, 2002; Koch, 2002; Magretta, 1998). However, other firms such as Nike (Smith, 2001) have had more problematic experiences selecting and implementing SCM IS. For smaller firms with less influence over their trading partners' processes and information systems, the difficulties can be considerable, although there are still numerous success stories (Dagenais & Gautschi).

In this chapter, we have attempted to make the selection of SCM IS a less risky decision for firms by providing a framework for analyzing the costs and benefits that can be expected for various types of SCM IS. The benefits of using SCM IS fall into two categories: reduced supply chain costs and enhanced responsiveness to market demands. Supply chain cost reduction benefits include reduced inventory levels, process costs, and product costs that result from the coordination of actual customer demand with supplier production plans. Enhanced responsiveness includes faster product-to-market cycle times, improved service levels (based on stock outs, lead times, and quality), and a better understanding of end-customer needs throughout the entire chain through market intelligence and demand visibility.

The costs of SCM IS include the total cost of ownership (TCO) of the IS and the partnership opportunity cost. TCO includes the total life-cycle costs of the chosen processes and systems, including cost of IS acquisition, usage, maintenance, dealing with errors and inefficiencies, and integration with partners over the lifetime of the system. The partnership opportunity cost is the benefits that are foregone from being constrained to trading with specific partners using the SCM IS. The partnership opportunity costs includes the costs of switching partners and costs of partnership instability, both of which are related to the transaction costs involved in searching, contracting, and establishing linkages with trading partners. Thus, high partnership opportunity costs could result from an inflexible system (such as EDI) that involves high costs of switching partners or a very flexible system (such as a public marketplace) that precludes long-term, stable trading relationships.

Using the cost-benefit model developed, together with an understanding of the processes and level of interorganizational integration required, firms can make better informed decisions about the type of SCM IS that will best fit their needs. While other factors such as the level of trust between the partners and the technical capabilities of the SCM IS are also critically important, the model presented helps ensure decision makers do not overlook important costs or benefits in their analyses. Using this model, researchers and practitioners can develop more realistic cost-benefit analyses of SCM IS and develop appropriate strategies to minimize their risks while maximizing the benefits of supply chain collaboration.

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Endnotes

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Chapter X

Applications: Collaborative Transportation and Consolidation in Global Third Party Logistics

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Abstract

This chapter introduces the applications of collaborative transportation and consolidation management in global third-party logistics. These practices are driven by the quest to improve service and reduce cost simultaneously under an e-commerce model of global supply chain management. The detailed development and elements of collaborative transportation and consolidation models are discussed along with case illustrations. Furthermore, a quantitative model using mathematical programming is developed to examine various consolidation policies in a global third-party logistics provider. A case using collaborative consolidation management is presented, and the results show a 6.6% and 18.2% improvement for service and cost comparing with existing practice. The collaborative principles and developed consolidation model can be a useful reference for similar applications.

Introduction

Due to escalating global competition and a decline in profit margins, most multinational corporations pursue global sourcing through a global supply chain (GSC) in order to secure market share and improve profits. The practice of e-commerce and the business trend of mass customization force both manufacturers and retailers to shorten cycle time by managing GSCs more effectively. Successful applications of GSCs, such as that by Dell Computer, have been widely discussed and publicized in the supply chain literature. However, the physical distribution of GSC execution is recognized as its weakest link and can result in inefficient and unreliable product delivery. The collaborative integration with global third-party logistics (3PL) to execute physical distribution dictates the success of any GSC application.

This chapter introduces a new shipper-carrier partnership strategy — collaborative transportation management (CTM) — as an application of GSC physical distribution. CTM is a new business model that includes the carrier as a strategic partner for information sharing and collaboration in a supply chain. Traditional international air transportation by consolidated freight takes eight to 14 days, excluding manufacturing lead time. An integrated global 3PL provider can act as a virtual distributor, allowing GSC participants to compress the delivery cycle time to two to four days.

The application of CTM promises to reduce transit times and total costs for the retailer and its suppliers while increasing asset utilization for the carriers. In an overall effort to minimize the system-wide cost, a global 3PL provider can apply various consolidation policies to maximize the utilization of capital-intensive transportation fleets, such as aircraft. Freight consolidation has received considerable attention in recent years, but the application of consolidation policies by an integrated global 3PL provider under an e-business model is rarely discussed. The trend of mass customization has challenged integrated logistics providers to adjust their consolidation policies in order to simultaneously minimize cost and fulfill service commitments.

This chapter examines a special class of freight consolidation at an integrated global 3PL provider that applies CTM when conducting business with its GSC partners. A mathematical programming model has been developed to assist with consolidation policy evaluation. The computational results reveal a substantial cost savings and a service level improvement of about 20% as a consequence of implementing a collaborative consolidation policy. Several managerial implications and benefits occurring after the global 3PL provider initiated the CTM business model with its business partners are discussed.

Background

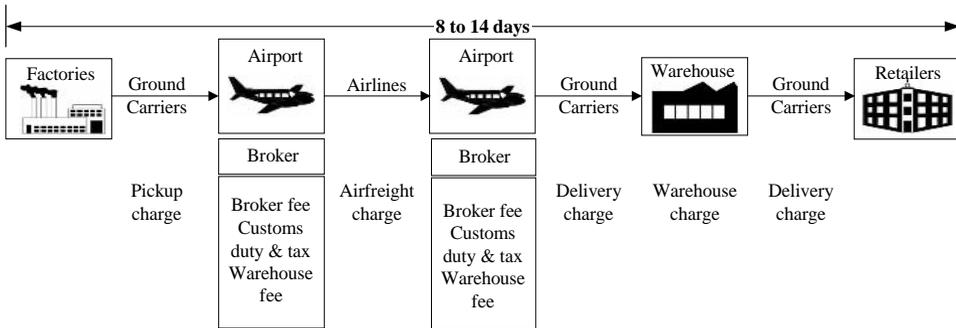
The key reasons for the globalization trend are overcapacity in highly industrialized countries, significant disadvantages with respect to labor costs, and the emergence of worldwide information networks that connect corporate information systems (Arnold, 1999). An increasing number of firms are combining domestic and international sourcing through GSCs as a means of achieving a sustainable competitive advantage (Bonarth, Handfield, & Das, 1998). A GSC is currently viewed as a strategic weapon in the quest for improved performance and profitability through greater availability, quality, delivery, and price advantage (H. L. Lee, 2000; Smith, 1999).

The principle and methodology of GSC management are similar to those of traditional supply chain management (SCM) except that multiple countries are taken into consideration. Traditional SCM is the integration of functions from the procurement of raw materials to final customer delivery. The GSC model is more complex than SCM, as it includes different taxes and duties, differential exchange rates, trade barriers, customs clearance, and a sophisticated international transportation network (Vidal & Goetschalckx, 1997). Most companies establish a virtual integrated enterprise with their suppliers by implementing an e-business model in order to address the information and finance flow of a GSC. However, the integration of physical distribution in a GSC appears to be the weakest link due to the high level of investment required when constructing a global distribution network.

The trends for e-commerce and mass customization via the Internet have challenged enterprises to deliver their completed orders within one week, as with Dell Computer's five-business-days model. The traditional international shipping practice with extensive consolidation operations (Crainic, 2000) takes eight to 14 business days, exclusive of manufacturing cycle time, as shown in *Figure 1*. The new economy calls for alliances to be made with 3PL providers in order to manage GSCs effectively by focusing on each player's core competencies (Aichlymayr, 2000b; Lieb & Randall, 1999). Most high-tech companies select global door-to-door 3PL providers such as FedEx, UPS, and DHL in order to streamline distributions and reduce delivery cycle times.

The typical benefits of a global door-to-door delivery service are shorter delivery cycle times, more reliable transit times, less complex customs clearance procedures, and real-time global tracking and tracing systems (Christopher, 1998). While the unit transportation cost is higher than that of traditional consolidated airfreight service, the total logistics cost is lower as a result of inventory and cycle-time reduction throughout the GSC. The success of these integrated 3PL providers is determined by their global transportation network, warehousing

Figure 1. Traditional International Consolidated Airfreight Model



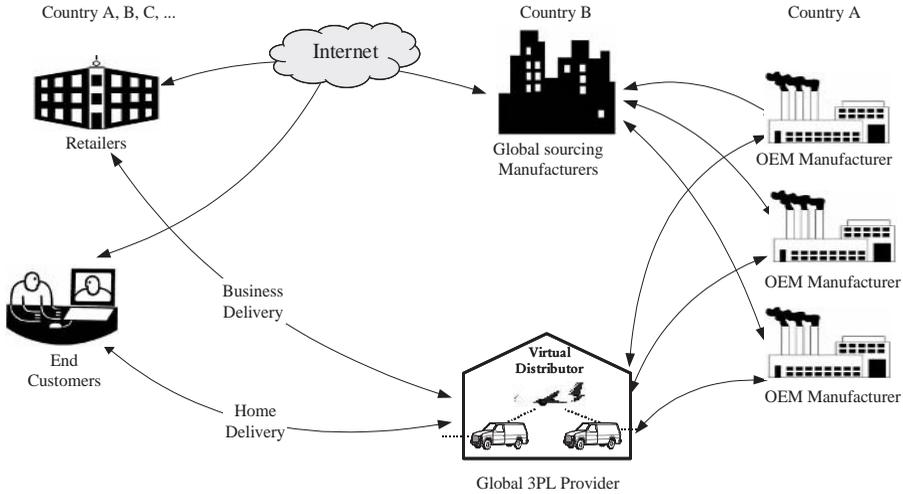
network, and information network. A GSC linked by a 3PL provider (see *Figure 2*) can reduce the distribution cycle from eight to 14 days to two to four days. The example depicts how business-to-business (B2B) and business-to-consumer (B2C) business models integrate global 3PL providers in a virtual distribution alliance with GSC participants to compress the delivery cycle time to two to four days.

The distribution alliance initiated by the integrated 3PL provider, as shown in *Figure 2*, is implemented by the principle and process recommended by CTM. The effective and efficient global delivery capability can attract additional business; however, buyers that use door-to-door delivery apply both build-to-order (BTO) and configuration-to-order (CTO) manufacturing models in order to minimize inventory cost. The demand of the BTO and CTO markets is highly volatile, as shown by the typical daily shipping pattern illustrated in *Figure 3*. In response to this order pattern, an integrated 3PL provider has to adjust its traditional freight consolidation strategies in order to simultaneously meet service commitments and maximize fleet utilization. Therefore, freight consolidation is another critical factor for any global 3PL provider when entering a CTM partnership with its respective GSC participants.

Collaborative Transportation Management

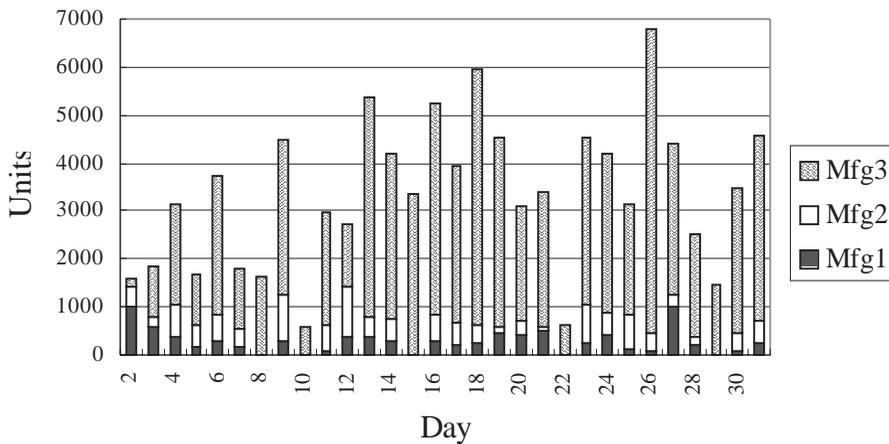
The level of collaboration amongst all players in the chain determines the success of a GSC. Classic supply chain collaboration is found in retailer and supplier partnership programs (Lummus & Vokurka, 1999) such as quick response,

Figure 2. GSC Linked by an Integrated 3PL Provider



continuous replenishment policy, and vendor-managed inventory (VMI), which aim to reduce inventory and provide a quick response to consumer demand. The most recent developments in collaborative planning, forecasting, and replenishment (CPFR) are designed to further improve the retailer-supplier relationship. However, the carrier relationship with supply chain players was not considered until the introduction of CTM, which extends the supply chain collaboration to physical distribution partners.

Figure 3. BTO Daily Shipment Trend for a 3PL Provider



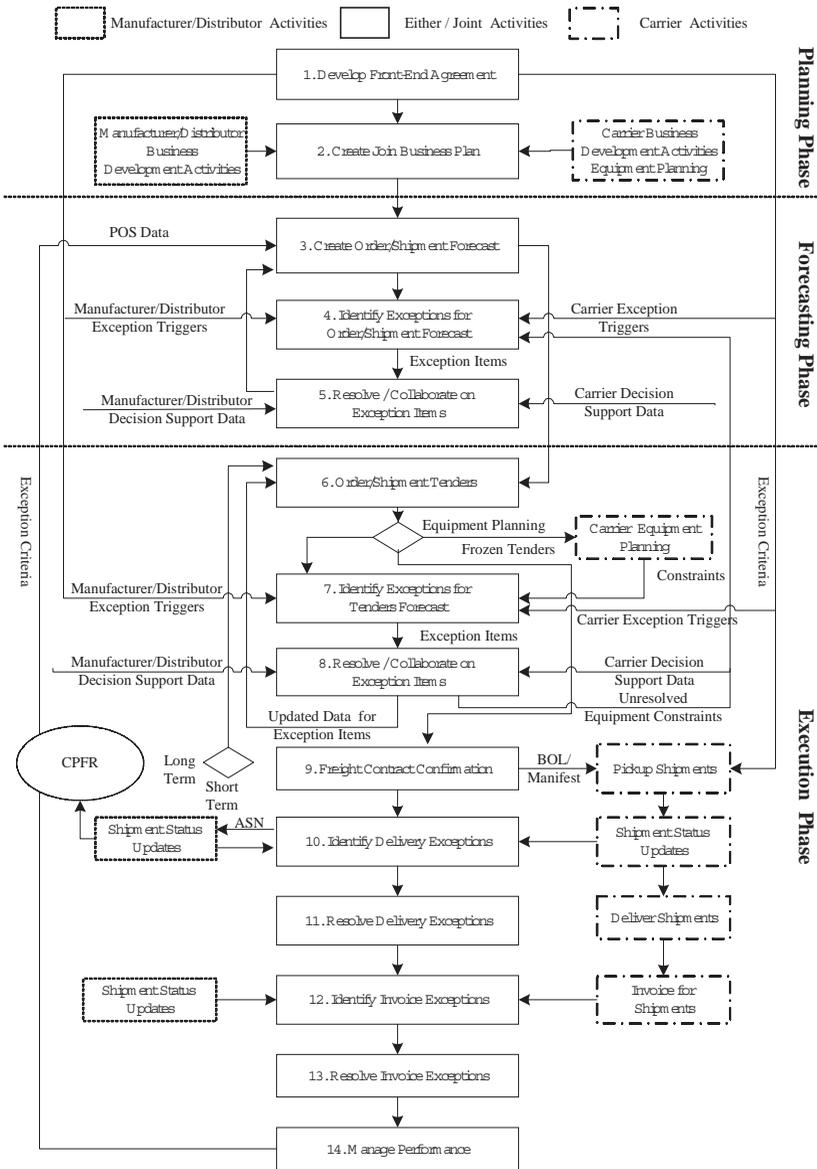
Historical Perspective

The historical perspective of both CPFR and CTM can be traced back to early VMI development for the retailer and supplier partnership. VMI — sometimes called rapid replenishment — is a “pull” replenishing practice designed to allow a vendor to quickly respond to actual demand. The motivation behind VMI strategy is that both parties work together to maximize the competitiveness of the supply chain. Under the VMI system, the supplier decides on the appropriate inventory levels of each product (within previously agreed bounds) and the appropriate inventory policies to maintain these levels (Simchi-Livi, Kaminsky, & Simchi-Livi, 2000). The most obvious benefits of the VMI arrangement are inventory cost reduction for the retailer and total cost reduction for the supplier. Improvements in productivity and service levels lead to larger profit margins and increases in sales.

In spite of the numerous benefits provided by VMI, a number of concerns has to be taken into account. Aichlymayr (2000a) investigated VMI implementation and reported that out of 10 VMI implementations, only three or four actually achieved any great success. Another three or four showed some benefits, but not as many as anticipated. Two or three showed no benefit whatsoever. To the best of our knowledge, there are two major deficiencies inherent in the VMI system that prevent it from enabling an efficient and agile supply chain. Firstly, the VMI system places too much responsibility on the manufacturer. Typically, the retailer dictates the rules so that the manufacturer has little choice but to comply. Furthermore, the manufacturer is responsible for any inventory discrepancy. The second deficiency is that the VMI system does not consider collaboration with distribution carriers. The capacity constraints of an individual carrier may distort supply chain efficiency by causing a delay in the distribution transit time. VMI appears to cause more delay effects in the GSC distribution of multi-airline and multi-carrier international transportation systems, as depicted in *Figure 1*.

CPFR was developed by the Voluntary Interindustry Commerce Standards Association (VICS) in order to address the first deficiency within VMI. CPFR is a nine-step business process model permitting value chain partners to coordinate sales forecasting and replenishment processes in order to reduce the variance between supply and demand (Aichlymayr, 2000a). Under CPFR, each party shares information and compares calculations. Manufacturers and retailers exchange forecasts, including point of sale (POS), on-hand, and delivery data. They review the data and collaborate to resolve forecasting discrepancies (Schachtman, 2000). A VICS subcommittee recently initiated a new shipper-carrier partnership strategy, known as CTM, in order to reduce transit times and inventory-carrying costs for the retailer and its suppliers while increasing asset

Figure 4. Generic CTM Business Model



Source: Browning and White, 2000

utilization for motor carriers (Cooke, 2000). CTM attempts to resolve the second deficiency within the VMI system.

CTM Business Model

The make-to-order market, driven by mass customization and e-commerce, is forcing retailers and manufacturers to shorten planning cycles, compress manufacturing lead time, and expedite distribution. With shorter planning windows and the overall objective of minimizing inventory in the value chain, transportation has become the most critical element in the process. Today, transportation is reactionary. Retailers, manufacturers, and carriers constantly find themselves in conflict when attempting to resolve shipment-level issues, which ultimately produces excess inventory and underutilized carrier equipment. CTM is an independent, yet concurrent, process with CPFR, building on the same relationships between retailers and manufacturers but incorporating new information and steps within the carriers. It extends CPFR's end-at-order confirmation, continues through to shipment delivery, and includes payment to the carrier. It then creates the carrier as part of supply chain player to reduce costs, increase asset utilization, improve service, increase revenue, and improve end-customer satisfaction.

CTM is a new process for carriers, involving them in five key business activities: the creation of a joint business plan, order forecasting, order generation, freight order confirmation, and carrier payment processes (Browning & White, 2000). The CTM business model was proposed by VICS and consists of 14 steps. The CTM process can be further divided into three distinct phases: planning, forecasting, and execution, as shown in *Figure 4*.

The planning phase makes up Steps 1 and 2. In Step 1, the trading partners establish a collaborative agreement to define the relationship in terms of freight shipment, exception handling, and key performance indicators. Step 2 involves aggregative planning to determine resource and equipment requirements by matching the planned shipment. The forecasting phase includes Steps 3 to 5. By sharing order and shipment forecasts in Step 3, the carrier gains insight into the planned volume changes and adjusts equipment requirements accordingly. Any exceptions caused by the manufacturer, distributor, or carrier are generated in Step 4 and resolved collaboratively in Step 5. Unlike the traditional one to two days' advance notice of potential shipments, the carrier has ample time to handle the revised volume — one to four weeks depending on the forecasting horizon.

The execution phase consists of four stages: shipment tenders, distribution, payment, and a review in order to manage the entire distribution cycle. The shipment tenders stage covers from Step 6 to Step 8 of the CTM process. Step

6 is the creation of order/shipment tenders based on the revised order forecast. Any exceptions based on the latest equipment availability or pickup and delivery requirements are identified in Step 7 and resolved collaboratively in Step 8. The distribution stage — Steps 9 through 11 — involves physical distribution and shipment status visibility. Step 9 is the creation of the final shipment contracts outlined in the collaborative tender acceptance and shipment terms. Shipment status is continually updated throughout the distribution cycle and any exception is identified during Step 10. Step 11 is the resolution of delivery exceptions. The payment stage is covered by Steps 12 and 13. Step 10 ensures that invoicing discrepancies between carriers and shippers are greatly reduced by the exchange of shipment attributes, such as weight, freight class, and destination. Any payment exceptions identified in Step 12 are collaboratively resolved in Step 13. Finally, the review phase in Step 14 involves measuring the distribution performance against the key performance indicators and seeking opportunities for continuous improvement.

CTM Implementation Issues

CTM is a new business model for integrating transportation management with SCM. The proposed CTM model is generic and can be modified to fit a specific supply chain application. We are interested in the application of CTM in a GSC from the perspective of a 3PL provider. The primary implementation issues are discussed next.

The benefits of CTM are the first issue to be addressed. Application of CTM provides individual benefits as well as supply chain benefits. The most obvious benefit to 3PL providers is the ability to develop business plans with their key customers in order to better fulfill distribution requirements. This is achieved through proactive participation in the planning, forecasting, and execution phases of CTM. The manufacturers and distributors consequently benefit from better transportation transit times, shipment status visibility, and the payment process. The collaboration in execution between trading partners creates supply chain competitiveness and value. Other benefits include reduced costs, increased revenue, an improved service level, improved customer satisfaction, and increased asset utilization (Browning & White, 2000).

CTM technology requirements are the next issue to be discussed. In order to foster collaboration, new information technology (IT) is needed to link between the carrier and the manufacturer/distributor. The CTM IT requirements proposed by VICS are vendor and platform independent, so that any trading partner entering into a collaborative relationship will not be hindered by technical limitations (Browning & White, 2000). The CTM information system integration

across the entire supply chain can be achieved by the development of IT standards, IT infrastructure, e-commerce, and a supply chain system (Simchi-Levi et al., 2000). In practice, a committee comprised of technical professionals from all trading parties handles the IT requirements and CTM integration.

Organizational infrastructure is another CTM implementation factor and is identified as the most important enabler of successful SCM implementation (Marien, 2000). It sets commitments and regulates all parties so they accept their responsibilities and share both the gains and risks, as outlined in Step 1 of the CTM business model. The GSC is a highly dynamic system and any changes may impact distribution activities. The core concept of CTM is to resolve these transportation exceptions collaboratively. In order to achieve the benefits of CTM, empowered designated personnel from each party are essential.

CTM Object Model

Figure 5 presents an integrated and evolutionary CTM framework based on object-oriented technology. In the framework, distributor and carrier data is managed by the object-oriented database. This provides capabilities for schema evolution, long transactions, and object reuse (Du & Wu, 2001). Data for both regular and exceptional orders can evolve from the forecasting stage to the confirmed stage and finally to resolved stage. Applications are maintained by the object paradigm. That is, functions such as collaborative strategies, performance management, contract management, and invoice management are written in object-oriented programs. In this case, reusability, encapsulation, and inheritance properties can be used to support a dynamic and highly interactive environment. This is particularly important for collaboration among distributors, manufacturers, and 3PL providers, as mission-critical information can be used to eliminate excess inventory from the entire supply chain and avoid meaningless exception processing.

CTM Freight Consolidation

While there have been few studies in the literature dealing directly with freight consolidation, several authors have studied shipment consolidation strategy in ground transportation applications. Shipment consolidation is the process of grouping different shipments from suppliers into a large shipment at the consolidation point. The motive behind consolidation is to take advantage of lower transportation rates through better utilization of a vehicle's capacity. The consolidation concept has been known for hundreds of years and the practices are widely used in rail, ground, sea, and air transportation.

policy, quantity policy, and time/quantity policy. The simulation result showed that the selection of a consolidation policy was determined by management's objectives with regard to cost and customer service.

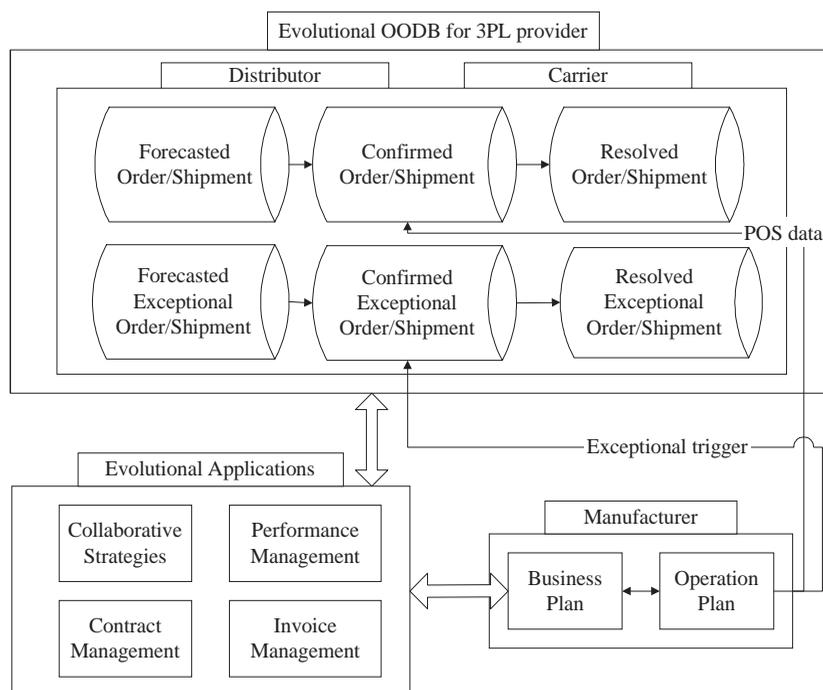
Problem Formulation

This study discusses the case of a global 3PL provider that provides door-to-door distribution services for major notebook (NB) manufacturers in Taiwan. Manufacturing capability as well as cost and quality advantages enables Taiwan to be one of the most competitive strategic NB computer suppliers for many of the major personal computer manufacturers, such as Apple, Compaq, Dell, HP, IBM, and Toshiba. About 50% of the world's notebook computers are manufactured in Taiwan. In order to reduce cycle times and total costs simultaneously for the BTO and CTO markets, Taiwan NB manufacturers transformed their international transportation from a consolidated airfreight mode to a door-to-door service. This practice is also called Taiwan direct shipment.

In order to enter the Taiwan direct-shipment distribution market, the global 3PL provider aligned with each NB manufacturer forms a specific GSC with its retailer. The representative GSCs and transportation network are shown in *Figure 6*. The global 3PL provider is allowed both a door-to-door and a consolidated freight service, with different price and delivery cycle times. The NBs are delivered to customers throughout North America using a door-to-door guaranteed service, with a cycle time of three to five business days. The partnership was started in late 1999. In the beginning, the 3PL provider experienced a major challenge in attempting to manage service levels and aircraft capacities due to the volume fluctuations of the BTO market. NB demand was highly volatile, as shown in *Figure 3*, which depicts daily shipments during a typical month. The aggregated daily shipment to the 3PL provider varied from 600 to 6,799, with a mean of 3,368 and a standard deviation of 1,535. The daily available aircraft capacity, on the other hand, could only accommodate about 4,000 shipments in that particular month.

In order to resolve the service level issue, the 3PL provider initiated a project to establish a CTM partnership with key NB shippers in early 2000. The project objective was to achieve a 95% service level by the end of 2000 for all NB shipments. The project team, which consisted of personnel from sales, technology, engineering, customer service, and operation fields, was responsible for CTM implementation with respective NB shippers. In the CTM planning phase, shipping agreements were outlined to include rate, expected delivery cycle time, pickup cutoff time, and maximum daily guaranteed volume. If shipments were

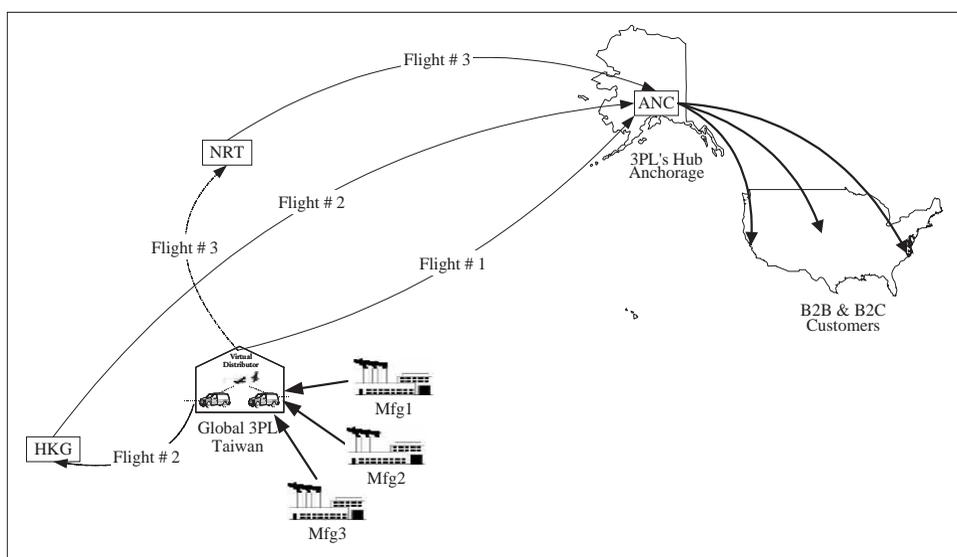
Figure 5. Object Model for Applying CTM to a 3PL Provider



Freight consolidation problems can be investigated in various forms. Hall (1987) introduced three strategies for consolidation: inventory consolidation, vehicle consolidation, and terminal consolidation. A mathematical model was later developed to examine the decision variables for each strategy. Gupta and Bagchi (1987) studied the minimum cost-effective lot size to be consolidated under a just-in-time procurement environment. A clearing model was constructed to calculate the minimum economic quantity at the consolidation center. C. Y. Lee, Cetinkaya, and Jaruphongsra (2000) applied a dynamic model to stock replenishment and outbound consolidation in a third-party warehouse. A polynomial-time algorithm was developed to simultaneously compute optimal lot size and order release decisions.

Structural simulation modeling is also commonly used to study the effects of freight consolidation. Pooley and Stenger (1992) developed an original algorithm and used a simulation approach to evaluate the logistics performance of a shipment consolidation program. Higginson and Bookbinder (1994) addressed the questions of how long customer orders should be held and the quantity which should be allowed to accumulate before a consolidated load shipment was dispatched. A simulation model compared three shipment release policies: time

Figure 6. Transportation Network of an Integrated Notebook-computer Global Supply Chain



over the daily guaranteed volume, an additional transit day was added to the delivery cycle time. The 3PL provider performed capacity requirement planning based on the planned demands from shippers. In the forecasting phase, shippers updated monthly and weekly shipment forecasts to the 3PL provider for aircraft capacity planning. As a result, the 3PL provider gained sufficient time to acquire additional aircraft capacities for month-end and quarter-end peak shipment demands.

In the CTM execution phase, IT integration was first identified to facilitate the collaboration. A new CTM integrator was developed by the 3PL provider to link with the manufacturer ERP system in order to retrieve shipping information in the shipment tender stage. Outbound and inbound customs clearances are required processes for international shipping. The shipment manifest and commercial invoice were transmitted to the 3PL provider through the CTM integrator before the actual shipment pickup in order to process preclearance (i.e., to prepare and submit customs clearance before the actual shipment arrived at customs), so as to eliminate customs delays. Once the shipments were picked up, a pickup confirmation notice was sent back to the manufacturer through the CTM integrator. A Web-API provided by the 3PL provider enabled the manufacturer to access the real-time tracking status via the Internet. The shipper would be notified of any delivery exceptions through e-mail and phone.

The customer, as well, could then check the delivery status via the Internet or through customer service. The IT integration of the CTM model in the GSC is shown in *Figure 7*.

The 3PL provider assigned a dedicated team to coordinate the CTM execution phase and proactively resolve any exceptions during shipment tender and delivery. In addition, the 3PL provider reviewed shipment forecasts and resolved any exception items through a daily cross-functional conference call. With the support of an integrated system, the 3PL provider could draw up an invoice with detailed proof of delivery in order to facilitate invoice exception identification and resolution. The 3PL provider consolidated daily and monthly delivery performance reports to the manufacturer by e-mail in order to manage delivery performance.

The CTM project was implemented progressively and three key shippers had entered into collaboration with the 3PL provider by June 2000. Through an aggregate planning process, the 3PL provider acquired additional aircraft capacity in October in order to accommodate volume growth. Two key performance indicators identified by the 3PL provider were the delivery service level, measured by percentage of on-time deliveries, and the delivery cycle time, measured by days. The delivery and cycle-time performance of the 3PL provider

Figure 7. Architecture of IT Integration of the CTM Model in a NB GSC

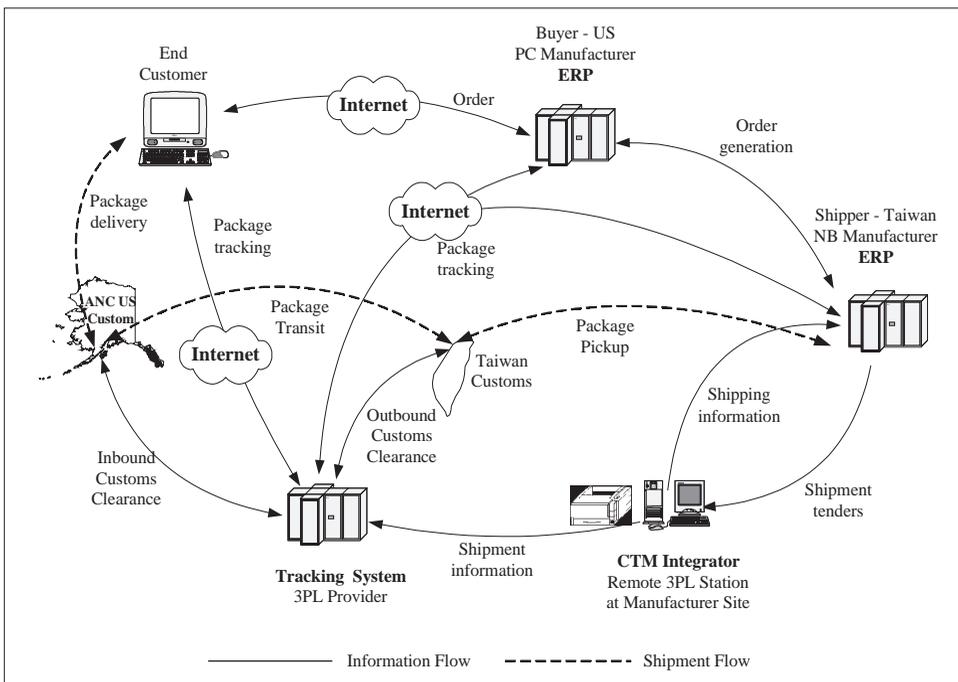
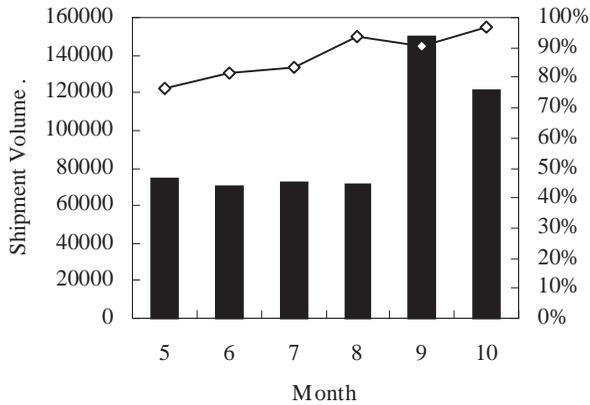


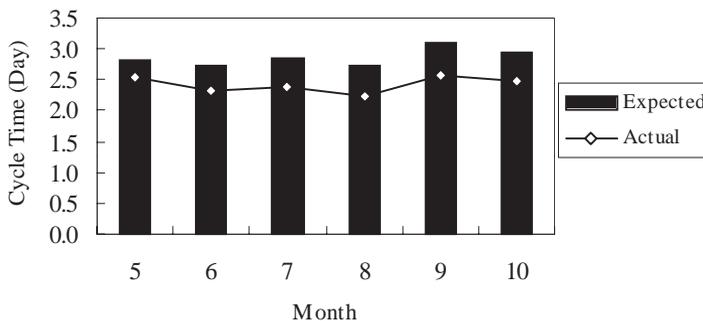
Figure 8. 3PL Provider Shipment Volume and Delivery Performance in the Year 2000



in 2000 are shown in *Figure 8* and *Figure 9*, respectively. Apart from September 2000, the service level achieved a progressive improvement. The actual average delivery cycle time was consistently smaller than the expected delivery cycle time, with a larger gap after the implementation of CTM in June 2000.

Before entering the Taiwan direct shipment NB business, the 3PL provider handled both consolidated airfreight and door-to-door express with percentages of 60% and 40%, respectively. With the focus on protecting on-time delivery, the 3PL provider jeopardized the service of airfreight customers as well as aircraft utilization. Therefore, the 3PL provider started to look into freight consolidation strategies in order to improve overall aircraft utilization as well as total revenue. The 3PL provider receives weekly shipment forecasts from manufacturers and

Figure 9. 3PL Provider Delivery Cycle-time Trend in the Year 2000

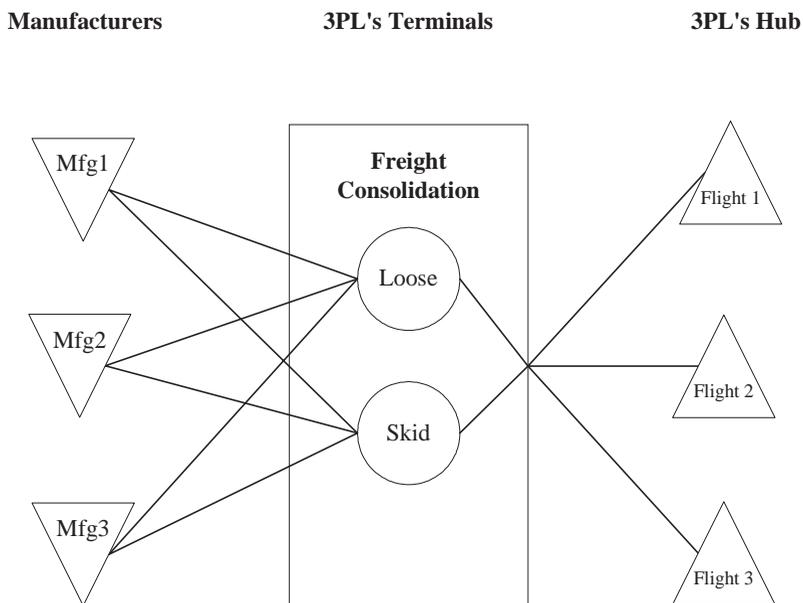


dispatches daily morning and afternoon pickups at shippers' factories. Combinations of inventory and vehicle consolidation strategies are implemented by the 3PL provider in order to maximize the truck utilization. The inventory consolidation primarily takes place at the manufacturer's shipping dock by accumulating all finished goods. A designated 3PL-provider staff member is on site to process the required shipping documents and to coordinate pickup operations. The vehicle consolidation is applied when the forecasted shipments are less than a truckload (LTL) for a single manufacturer. The consolidation shipments are then trucked back to the 3PL provider's terminals for subsequent consolidation into a unit load device (ULD) for final aircraft loading. All ULDs are loaded into three alternative flights for delivery throughout the US.

The morning and afternoon pickup service commitments are for the next business day and two business days, respectively. Each completed NB is packed individually and various brands and models have similar sizes and weights. The size and weight of each packed NB are assumed to be identical in this study in order to facilitate the development of a mathematical model by using an aggregate volume for all shippers.

The scope of the freight consolidation study covers the consolidation decisions at the 3PL provider's terminals and the selection of alternative flights. A network representation of a freight consolidation model is shown in *Figure 10*. The

Figure 10. A Network Representation of the Freight Consolidation Model



occurs in skid consolidation mode and is assumed to be a fixed load factor for each skid ULD.

In order to introduce the general form of the freight consolidation model, we will define the following terms:

- **Input to the consolidation model:**

- l_k : unit linehaul cost for flight k
- c_j : unit consolidation handling cost for shipment mode j
- h_j : unit holding cost for shipment mode j
- p_j : unit penalty cost for late shipment mode j
- m : minimum profit per ULD
- f : load factor for pure skid loaded ULD
- F_{ik} : flight capacity for flight k on day i
- S_{ij} : quantity of shipment mode j to be shipped on day i
- N_{ij} : quantity of shipment mode j to be shipped no later than day $i+1$

- **Decision variables:**

- x_{ijk} : quantity of shipment mode j picked up on day i to be shipped by flight k
- y_{ij} : quantity of held shipment mode j on day i
- z_{ij} : quantity of late shipment mode j on day i
- u_i : quantity of pure skid loaded ULD on day i

where the shipment mode is defined as the freight transportation event.

- **Policy A formulation:**

$$\min \sum_i \sum_j \sum_k x_{ijk} l_k + \sum_i \sum_j \sum_k c_j x_{ijk} + \sum_i \sum_j h_j y_{ij} + \sum_i \sum_j p_j z_{ij}$$

subject to

$$\sum_j x_{ijk} \leq F_{ik} \text{ for every day } i \text{ and flight } k; \quad (1)$$

$$\sum_j \sum_k x_{ijk} \geq \sum_j S_{ij} + y_{(i-1)j} \text{ for day } i \geq 2; \quad (2)$$

$$\sum_k x_{ijk} + y_{ij} = S_{ij} + N_{ij} \text{ for every shipment mode } j \text{ and day } i=1; \quad (3)$$

manufacturer packs B2C orders as loose cartons and B2B orders as skids consisting of 40 cartons. The 3PL provider consolidates loose and skid shipments at its cargo and express terminals, respectively. The flight capacity allocations for NB direct shipments vary according to the flight and day of the week. Three consolidation policies are developed to minimize the total cost and to meet the service requirements. Policy A represents the “as is” practice. Policy B considers breaking skid shipments into loose mode in order to take advantage of ULD utilization. Policy C further improves the service level by loading afternoon pickups the same business day when flight capacity is still available. The consolidation policies are summarized in *Table 1*.

Mathematical Programming Model

A mathematical programming model (Tyan, Wang & Du, 2003) can be developed to compute the total cost of this freight consolidation model while satisfying capacity and service constraints. The total cost can be decomposed into two subsequent components — operating cost (OC) and capacity lost cost (CLC) — as follows:

$$Total\ Cost = OC + CLC$$

where OC = Linehaul cost + Consolidation operating cost + Inventory holding cost + Penalty cost. The linehaul cost represents the company internal allocation cost for the air transportation section since the global 3PL provider operates its own aircraft fleet, and is based on the accumulated flying mileage. The consolidation operating cost includes labor cost, customs clearance fee, capital depreciation, and related operating expenses. Inventory cost occurs when the shipments are held in terminals and it is a fixed unit cost for the first three days of this study. The penalty cost is the money-back guarantee cost in case of service failure. The CLC is the expected revenue loss for any LTL’s ULD. The load factor is defined as the percentage of a ULD’s utilization. In this case, it only

Table 1. Description of Three Freight Consolidation Policies

	<i>Package mode</i>	<i>Consolidation point</i>	<i>Service requirement</i>
Policy A	Loose and skid	Express and cargo terminals	Just-in-time
Policy B	Loose only	Express terminal	Just-in-time
Policy C	Loose only	Express terminal	Improved service

$$\sum_k x_{ijk} + y_{ij} = S_{ij} + N_{ij} + y_{(i-1)j} + z_{ij} \text{ for day } i \geq 2; \quad (4)$$

$$\sum_j z_{ij} \leq \sum_j y_{ij} \text{ for day } i \geq 2; \quad (5)$$

x_{ijk} , y_{ij} , z_{ij} are nonnegative integers.

The purpose of Policy A formulation is to minimize OC while satisfying capacity constraints and the service commitments. Constraint 1 ensures that the total boarded shipments do not exceed the total flight capacity. Constraint 2 ensures that the total boarded shipments are greater than total morning pickups plus on-hold shipments from the previous day. It guarantees the next business day delivery commitment. Constraints 3 and 4 set the relationships of inbound and outbound shipments at each consolidation terminal. Constraint 5 indicates that the late shipments are subsets of on-hold shipments. The model will then yield the optimal values for decision variables to minimize the OC. Once the x_{ijk} is identified, then the CLC is computed as:

$$u_i = \sum_k \lceil x_{i2k} / 6 \rceil \text{ for every day } i; \quad (6)$$

$$\text{CLC} = \sum_i m(1-f)u_i. \quad (7)$$

It is worth noticing that a typical cargo freighter has both upper and lower cargo compartments. A variety of containers or ULDs of special size and shape is designed to fit into these cargo compartments. The ULD used in this study is a container that can hold 330 units of NBs and can be placed in the upper cargo compartment only. Due to the size and shape of skid shipments, only six skids (240 units) can be loaded into the ULD, which converts to a load factor of 72.7%. With the facility constraint and operational requirements, the six skid-loaded ULDs are unable to top up other cargo, which results in potential revenue loss cost. In order to simplify the calculation, the load factor of the last loaded ULD with skid shipments for each flight is assumed to be the same as 72.7%, even if it is less than six skids. Once the CLC is calculated using Formulas 6 and 7, the total cost is the sum of the OC and the CLC.

- **Policy B formulation:**

$$\min \sum_i \sum_j \sum_k x_{ijk} l_k + \sum_i \sum_j \sum_k c_j x_{ijk} + \sum_i \sum_j h_j y_{ij} + \sum_i \sum_j p_j z_{ij}$$

subject to

$$\sum_j x_{ijk} \leq F_{ik} \quad \text{for every day } i \text{ and flight } k; \quad (8)$$

$$\sum_j \sum_k x_{ijk} \geq \sum_j S_{ij} + y_{(i-1)j} \quad \text{for day } i \geq 2; \quad (9)$$

$$\sum_j \sum_k x_{ijk} + \sum_j y_{ij} = \sum_j S_{ij} + \sum_j N_{ij} \quad \text{for day } i \geq 1; \quad (10)$$

$$\sum_j \sum_k x_{ijk} + \sum_j y_{ij} = \sum_j S_{ij} + \sum_j N_{ij} + \sum_j y_{(i-1)j} + \sum_j z_{ij} \quad \text{for day } i \geq 2; \quad (11)$$

$$\sum_j z_{ij} \leq \sum_j y_{ij} \quad \text{for day } i \geq 2; \quad (12)$$

x_{ijk} , y_{ij} , z_{ij} are nonnegative integers.

Policy B requires the same service level as Policy A, so the formulation is similar. The changes in Constraints 10-11, compared with Constraints 3-4, indicate that the skid shipments are broken into loose units and mixed with loose shipments for consolidation. The consolidation of loose shipments takes place in the 3PL provider's express terminal, where other types of express shipments with the same flight can top up the ULD with loose shipments. This implies that Policy B will not incur any lost capacity, so the total cost degenerates to OC.

- **Policy C formulation:**

$$\min \sum_i \sum_j \sum_k x_{ijk} l_k + \sum_i \sum_j \sum_k c_j x_{ijk} + \sum_i \sum_j h_j y_{ij} + \sum_i \sum_j p_j z_{ij}$$

subject to

$$\sum_j x_{ijk} \leq F_{ik} \quad \text{for every day } i \text{ and flight } k; \quad (13)$$

$$\sum_j \sum_k x_{ijk} = \sum_j S_{ij} + \sum_j N_{ij}, \text{ if } \sum_j (S_{ij} + N_{ij}) \leq \sum_k F_{ik} \quad \text{for every day } i; \quad (14)$$

$$\sum_j \sum_k x_{ijk} + \sum_j y_{ij} = \sum_j S_{ij} + \sum_j N_{ij}, \text{ if } \sum_j (S_{ij} + N_{ij}) > \sum_k F_{ik}$$

for every day i ; (15)

$$\sum_j \sum_k x_{ijk} + \sum_j y_{ij} = \sum_j S_{ij} + \sum_j N_{ij} + \sum_j y_{(i-1)j} + \sum_j z_{ij} \text{ for day } i \geq 2; \quad (16)$$

$$\sum_j z_{ij} \leq \sum_j y_{ij} \text{ for day } i \geq 2; \quad (17)$$

x_{ijk} , y_{ij} , z_{ij} are nonnegative integers.

Policy C possesses consolidation characteristics with additional delivery service improvements. This is reflected in Constraint 13, which specifies that all morning and afternoon shipments have to be shipped if the total flight capacity is greater than the total number of pickups on that day. This policy provides a trade-off between improved service levels and increased operating costs.

Computational Results and Managerial Implications

The mathematical programming models presented in the previous section can provide significant managerial insights for making consolidation decisions. This section intends to examine consolidation policy effects through computational analysis. The model parameter data is obtained from a global 3PL provider company with some modifications. The Lingo 5.0 system (Lingo Systems, 1999) is used to construct mathematical programming models for all three policies. The computational times for Policies A, B, and C on a Pentium III 750 Mhz PC are 7, 8, and 8.5 seconds, respectively. Both trend analysis and sensitivity analysis are provided to derive the managerial implications.

According to the NB shipping pattern and capacity schedule at the 3PL provider company, one week is set as the planning horizon for computational analysis. The input parameters and the shipment data for the first week of a selected month are summarized in *Table 2*. The skid shipment unit (S_{iz} and N_{iz}) is the number of skids, with each skid consisting of 40 units. The loose shipment unit (S_{il} and N_{il}) is the number of packages. The shipment data is the aggregate volume from three manufacturers. The allocated flight capacities are converted to number of packages. All cost data is shown in US\$ per package. The expected revenue is US\$980.10 per ULD and is used to calculate the CLC.

Table 2. Aggregate Shipments and Model Parameters

Day	S_{i1}	N_{i1}	S_{i2}	N_{i2}	Total units	F_{i1}	F_{i2}	F_{i3}
1	83	264	5	4	707	3960	3960	3300
2	833	0	5	4	1193	4290	3960	3300
3	257	352	18	1	1369	3960	3960	3300
4	1146	305	74	125	9411	3300	3960	3300
5	0	1362	0	49	3322	2970	3960	3300
6	0	480	0	2	560	2640	5610	0
7	0	0	0	0		7920	0	0
c_1	c_2	h_1	h_2	p_1	p_2	l_1	l_2	l_3
.43	.172	.3	.3	12.21	11.22	9.24	9.57	9.9

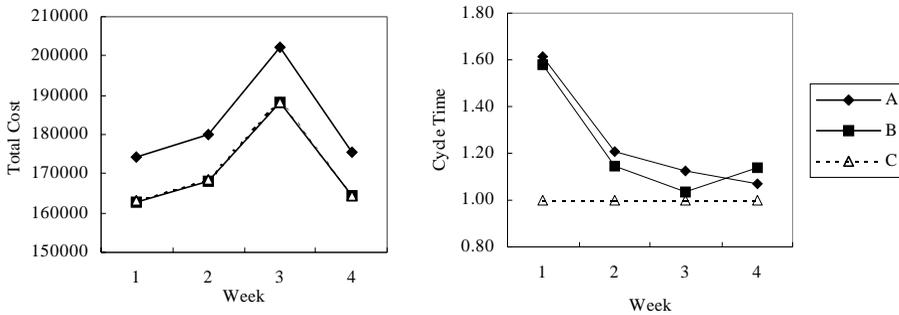
The Policy A model for each week consists of 70 integer variables and 50 constraints. This problem can be solved within a minute using the Lingo 5.0 system. The weekly total cost and delivery cycle-time trends in the selected month are summarized in *Table 3* and shown in *Figure 11*. Policy B and Policy C yield a 6.7% total cost-savings benefit when compared with Policy A. The total costs of Policy B and Policy C do not have any significant differences. The service level measured by delivery cycle time shows that Policy B is better than Policy A by 2.4%, while Policy C achieves a 20.2% better service level than Policy A.

These results present several managerial implications. Firstly, the daily shipment allocation by flight, as shown in *Table 4*, can assist management in conducting capacity planning. This is extremely helpful to the 3PL provider when conducting weekly capacity planning by considering the forecasted volume in the consolidation model. The freight sales professional can then sell the unallocated space by flight in order to maximize overall load factors. The second implication is drawn from the total cost savings of Policies B and C in comparison with Policy A,

Table 3. Total Cost and Delivery Cycle Time in the Selected Month

Week #	Total Cost			Average Cycle Time (day)		
	Policy A	Policy B	Policy C	Policy A	Policy B	Policy C
1	174366	162870	162997	1.61	1.58	1.00
2	180101	168261	168299	1.21	1.15	1.00
3	202355	188244	188253	1.12	1.03	1.00
4	175661	164252	164287	1.07	1.14	1.00
Average	183121	170907	170959	1.25	1.22	1.00

Figure 11. Total Cost and Cycle-time Trends Under the Three Policies in a Particular Month



translating into a 6.7% profit improvement. Although the savings are attractive, the application of these policies requires additional coordination with internal departments and shippers in order to ensure that the consolidation process does not jeopardize B2B delivery commitments by splitting the shipments along the 3PL provider’s transportation network. Furthermore, Policy C appears to be the most favorable strategy under a CTM alliance since both the carrier and the shipper benefit from simultaneous cost savings and improved service.

The effects of the total cost with a change of model parameters provide another aspect from which to evaluate the three consolidation policies and to make “what if?” decisions. The analysis is done through sensitivity analysis on flight capacities, shipment volume, minimum ULD profit, and the load factor for skid-loaded ULD. The data for the analysis is based on the first week of the selected month, as shown in Table 2. The change of freight capacity affects shipment allocations and the total cost. The results of changing capacities, in terms of the

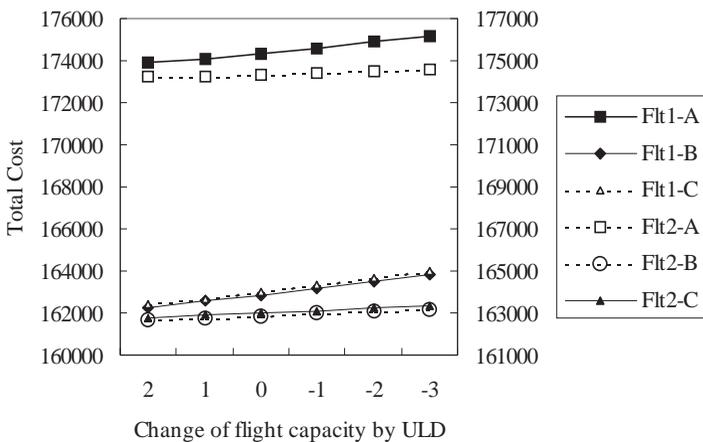
Table 4. Daily Shipment Allocation by Flight for the First Week in the Selected Month

i	Loose Shipment Allocation				Skid Shipment Allocation			
	x_{i11}	x_{i12}	x_{i13}	y_{i1}	x_{i21}	x_{i22}	x_{i23}	y_{i2}
1	347	0	0	0	9	0	0	0
2	833	0	0	0	9	0	0	0
3	609	0	0	0	19	0	0	0
4	1430	0	0	21	34	72	4	89
5	1375	0	0	8	29	72	0	37
6	488	0	0	0	39	0	0	0
7	0	0	0	0	0	0	0	0

ULD, show that Flight #1 has a greater impact than Flight #2, and Flight #3 has no significant cost impact. The scale of the cost effect becomes larger when the ULD reduction unit is larger, as shown in *Figure 12*. This implies that allocating capacity to Flight #1 is the most favorable selection in reducing total cost. Another observation indicates that, when changing the shipment volume, the fundamental cost structures of the three consolidation policies remain the same. This suggests that the selection of the consolidation policy will not be affected by volume fluctuations.

The analysis of changing ULD profits and load factors provides valuable suggestions concerning how to manage consolidation operations with Policy A. The increase in the total cost is proportional to the increase in net profit per ULD. When the ULD profit improves by 20%, the total cost rises by 1.6%. This means that accepting skid shipments from NB manufacturers becomes unfavorable if the 3PL provider can find a more profitable product. This is practically true in the express industry since the global 3PL provider can easily find a regular overnight product to replace the skid shipments, with a yield at least 3 times greater. For increasing values of the ULD's load factor, the total cost drops consistently. The "break-even" point when selecting Policy A instead of Policy B in terms of total cost occurs at $f = 95.7\%$ by taking advantage of the lower consolidation operation cost of skid shipments. This can be achieved by redesigning the skid size, in cooperation with the shippers, so it can better fit the ULD in order to maximize the load factor. A summary of the computations is shown in *Figure 13*.

Figure 12. Effect on Total Cost with the Change of Flight Capacity



and weights. Moreover, the relaxation of the ULD constraint presents another practical application, since each cargo freighter consists of combinations of various types of ULDs. Furthermore, the consolidation problem can be investigated by a simulation approach. Simulation modeling of the problem can examine dynamic behaviors of consolidation operations and so provide further insights to those who execute such operations.

Conclusions

The trends of globalization and mass customization challenge the traditional single enterprise to respond and meet market demand. The new economy calls for alliances to be made with 3PL providers in order to form a GSC that focuses on the core competencies of each player. Companies that have implemented a GSC, such as Dell and Compaq, have gained a higher market share, improved profit margins and services, and increased response times to BTO and CTO demands. GSC management has become a strategic tool for reducing costs as well as enhancing a company value.

With the introduction of the CTM model, the carrier is able to establish collaboration with the manufacturer and retailer during the planning, forecasting, and execution phases of the GSC execution process. CTM brings to the carrier the benefits of better strategic capacity planning, increased asset utilization, and an improved delivery service level. In return, the manufacturer enjoys reduced costs, improved delivery reliability, increased visibility, and increased revenue. The illustrated NB GSC case shows that CTM is an effective approach for 3PL providers to deliver benefits to all parties in the supply chain.

Freight consolidation is identified as another opportunity for the global 3PL provider to realize the full benefits of the CTM application. In an attempt to minimize the system-wide cost, the global 3PL provider can apply various consolidation policies in order to maximize aircraft utilization while simultaneously maintaining its service commitments. In this study, three consolidation policies, designed to minimize the total cost under capacity and service requirement constraints, were developed. The problem was formulated as a mathematical programming model. The optimal solution specified the shipment quantities that should be allocated to alternative flights each day so that service requirements are satisfied at minimal cost.

The consolidation model was then constructed using Lingo 5.0 to provide computational analyses. The results showed that using collaborative consolidation policies, such as Policy B and Policy C, can achieve average cost savings of 6.7% over existing practices, namely, Policy A. Furthermore, Policy C

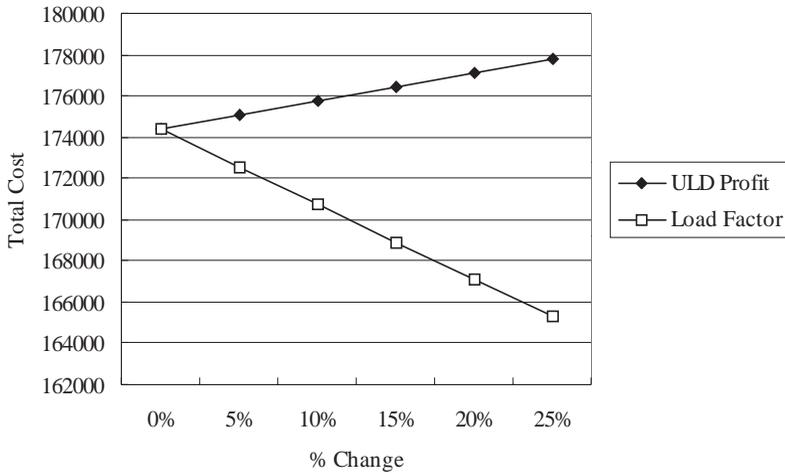
delivers an 18.2% greater service level than Policy B, with only a slight cost increase of less than 0.1%. From the sensitivity analysis, we can conclude that, when considering simultaneous cost reduction and service improvement, Policy C is the most favorable policy.

The study indicated that a collaborative consolidation policy can benefit both the carrier and shipper concurrently. Although this case was developed using a specific global 3PL provider application, the modeling methodology and its managerial implications can be easily adopted by other applications in the context of consolidation in the freight distribution industry.

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Figure 13. Effect on Total Cost with the Change of ULD Profits and Load Factors of Policy A



Future Trends

E-collaboration has emerged as the new focus for supply chains seeking additional business and cost savings. Early adopters of e-collaboration, such as retailer chains, apply CPFR and CTM to synchronize manufacturing and shipping activities. Drug Store News (*E-collaboration Leads Chains to E-savings*, 2001) reported a CPFR case in which inventories for retailers have been reduced as much as 14%, while business has increased about 32%. Dutton (2003) reviewed a CTM application between Procter & Gamble and J.B. Hunt to include shipping into the supply chain. Carrier J.B. Hunt reported a 16% decrease in unloading time and a 3% drop in empty miles because of information sharing.

The success of e-collaboration in retailing chains motivates other industries to follow. This chapter examines the case of a global 3PL provider engaging in e-collaboration among supply chains across continents. The principles and implications of the CTM application discussed can be generalized to cover other applications. The developed freight consolidation models can be a reference model for similar global 3PL providers that operate their warehousing and fleets.

The freight consolidation research can be extended in several ways. One possible extension is to relax the assumption of a fixed size for each package, since most industry applications handle a number of packages of different sizes

Chapter XI

Ethical Dimensions in Collaborative Commerce

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Abstract

This chapter deals with ethical dimensions in the environment of collaborative commerce. An ethical failure model is developed based upon failure concepts borrowed from the quality profession. Five types of collaborative commerce are presented, followed by a discussion of their typical flows and characteristics. In addition, four major business ethics issues and six potential ethical issues in collaborative commerce are delineated.

Fusaro & Miller, 2002). Although Enron may have been stated by *Fortune* magazine as one of America's "most admired companies," its blind adherence to a misguided notion and unethical practice of how to apply market discipline to its internal operation has contributed greatly to its downfall (Fusaro & Miller, 2002).

On the other hand, the important idea involved in the discussion of ethics in collaborative commerce is that the ethical issues associated with the concept of ethical failures can be considered as a very specific type of quality failures caused by human beings under a conscious state. As a result, a failure model developed from the quality point of view is judged to be equally applicable to the ethical failures. In the meantime, for the development of the failure model, the ethical failures based on weaknesses and threats at the individual and corporate levels are identified.

For the discussion of the ethical issues in business, four major business ethics issues are identified; they are conflict of interest, honesty and fairness, communications, and technology. Subsequently, the potential ethical issues in collaborative commerce at various levels, from the corporate level to the operational level, are collected and analyzed by categories based on the business ethics and information ethics issues that are closely related to the collaborative commerce.

In our discussion of ethics in collaborative commerce, the best way to maintain the competence and growth of the business operation for a company is that the company should have good practices for the various kinds of ethical issues. To encourage ethical behaviors, the company must be responsible for developing an ethics program for preventing misconducts. This program should provide employee training which includes understanding of a code of ethics, identification of common ethical issues, methods for employees to report misconduct, and a provision for monitoring and enforcing the program.

Collaborative Commerce Model and Its Characteristics

This section discusses the collaborative commerce model and its characteristics. Generally speaking, there are five collaborative types in collaborative commerce. These five types will be discussed in this section, followed by the flow of collaborative commerce and characteristics of collaborative commerce.

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Introduction

Collaborative commerce is defined as using digital technologies to carry out buy-and-sell business activities, such as planning, designing, developing, researching, and service. This type of collaboration integrates business processes between partners through sharing information electronically (Li & Du, 2003). Collaborative commerce opens up new and unregulated business activities or processes, in which it is not clear to people how to follow what is right or wrong according to current knowledge. It needs to redefine or reregulate business rules for this new environment.

In this chapter, five collaborative types are identified in collaborative commerce: one to one, one to many, many to one, many to many, and collaborative cooperation, from the business collaboration viewpoint of B2B commerce (Rau, 2003; Turban, King, Lee, Warkentin, & Chung, 2002).

Subsequently, flows and characteristics of collaborative commerce are discussed. For our discussion, a three-partner model — producer, first-tier buyer, and second-tier buyer — is used as an example to demonstrate the flows of collaborative commerce. Furthermore, under an electronic collaborative commerce environment and in contrast with traditional commerce, there are three characteristics identified, namely, system dominant, digital information intensive, and partnership dependent. With these three characteristics, in ordinary practices, participant companies and people would enjoy the business collaboration in order to win business competition; however, on the other hand, it might turn out to be a big disaster when a flaw occurs in the system either intentionally or unintentionally. This resulting damage could spread wider and quicker, and the effects of intentional or ethical flaws would lead to ethical issues in collaborative commerce.

On the one hand, business ethics is important not only for the proper business practice but also for the public's image of the integrity of the various tiers of managers in business. In addition, huge amounts of investment funds might be in jeopardy should an unethical event be uncovered. Using the Enron Company, for example, the financial scandal case with Enron was the first of the recent business scandals that have devastated investor faith, contributed to a multi-trillion-dollar market downturn, and made corporate reform a political imperative (Behr & Witt, 2002).

Enron hailed 2000 as a breakout year with slightly more than \$100 billion in revenue, putting it at No. 7 on the list of the largest US corporations. However, following the breakout of the scandal, the Enron stock price fell from an all-time high of \$90.60 in August 2000 to a fraction of a dime now (Behr & Witt, 2002;

Collaborative Types

As mentioned before, collaborative commerce is defined as using digital technologies to carry out buy-and-sell or provide-and-receive business activities, such as planning, designing, developing, researching, sales, and service. This type of collaboration integrates business processes between partners through sharing resources electronically, especially information.

As shown in *Table 1*, from the business collaboration viewpoint, there are five types of B2B commerce (Rau, 2003; Turban et al., 2002).

- (1) *One-to-One Type*: One business to one business commerce is a basic commerce interactive form between two companies or organizations. They could transact all kinds of information related to business products or services over the Internet or Web, such as order fulfillment, design or process technologies, etc. This basic form could be extended into a supply chain. Almost all national or international companies execute this type of commerce. Taiwan Semiconductor Manufacturing Company (TSMC) uses the portal system eFoundry (www.tsmc.com) to do business with customers, who can monitor key information through online access to engineering and electronic supply chain information, such as purchase orders, work-in-process reports, shipping notices, and other important logistical information. The TSMC eFoundry suite currently supports online services categorized into design, engineering, and logistics three collaborations.
- (2) *One-to-Many Type*: This type belongs to the sell-side marketplace, which is sometimes referred to as a private e-marketplace. The sell-side marketplace provides a Web-based, private-trading sales channel, frequently over an extranet, to business customers. In this type, both individual consumers and business buyers may use the same sell-side marketplace (Aldin & Stahre, 2003). There are many examples in this type, such as Dell and Cisco. Customers at Dell get personalized pages at Dell Online Premier (www.dell.com), where they can buy goods, track activities, and view historical activities. Cisco's CCO (Cisco Connection Online) (www.cisco.com) provides online pricing and sales, configuration tools, and order status tracking.
- (3) *Many-to-One Type*: This type belongs to the buy-side marketplace, which is used for procurement. The traditional purchasing process is very inefficient and spends too much time on non-value-added activities, such as paperwork, data entry, and expediting delivery. In addition, for management it is hard to control the ethical problems between purchasing personnel and vendors. Meanwhile, the large buyers can not take advantage of their buyer powers when they buy products or services from the sell-side

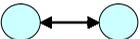
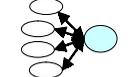
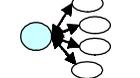
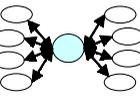
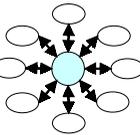
marketplace. Moreover, searching e-stores or e-malls to find and compare suppliers and products can be very slow and costly. Due to these reasons, it is worthwhile for large buyers to open their own e-marketplace, which we call the buy-side marketplace. Under this type, a buyer opens an electronic market on his own server and invites potential suppliers to bid on the items. In many bidding systems, a common method for purchasing uses reverse auctions. Through this kind of e-commerce, the buyer can increase purchasing agent productivity, lower purchase prices, find new suppliers, etc. There are many examples occurring at big companies with big buying power, such as GE's Trading Process Network (TPN) Post (www.gxs.com) and Formosa Plastics Corporation's Formosa Technology Electronic Commerce (FTEC; www.e-fpg.com). GE's TPN Post system is one of the first initiatives; it started from an electronic tendering system for GE's Lighting Division. It improves the productivity of the buyers' sourcing process and allows buyers to access quality goods and services from around the world. FTEC is a purchasing net for the needs of Formosa Plastics Corporation, and its suppliers are located mainly in Taiwan and China.

- (4) *Many-to-Many Type*: In contrast with the company-centric types mentioned in (1) to (3), this type is a public e-marketplace and involves transactions among many sellers and many buyers. It is known under a variety of names: e-marketplace, exchange, trading exchange, exchange hub, etc. The marketplace is where many buyers and sellers meet electronically for the purpose of trading electronically with each other. ChemConnect (www.ChemConnect.com) and Covisint (www.Covisint.com) are two of many examples. ChemConnect helps buyers and sellers of chemicals, plastics, and related products optimize their purchasing and sales processes. Global industry leaders, such as British Petroleum, Dow Chemical, BASF, Sumitomo, Shell Chemicals, Hyundai, and many more, make transactions here every day in real-time. They save on transaction costs, reduce cycle time, and find new markets and trading partners around the world. Covisint is a buyer-side e-marketplace of the automotive industry, with members GM, Ford, Chrysler, Renault, Peugeot Citroen, and Nissan, for purchasing with about 30,000 suppliers. Covisint offers its customers best-of-breed functionality from multiple technical providers that integrate across the supply chain, create a unique collaborative environment for product design and development, enable an e-procurement process, and provide a broad marketplace of buyers and suppliers.
- (5) *Collaborative Cooperation Type*: There are many varieties of this type, including joint design, planning, forecasting, production, logistics, and service. Using Web-based communications, this type forms a hub to allow an enterprise and its business partners to share information or resources online in real time or allow all parties to work together on the Web to

complete a mission. These activities are conducted between and among supply chain partners. Sun Microsystems (2001) performed collaborative product commerce to make product development come together with its partners and shares design and production information in real time from anywhere on the globe. Webcor Builder (www.Webcor.com) uses the ProjectNet software that hosts Webcor’s projects. The partners can post, send, or edit CAD drawings, digital photos, memos, status reports, and project histories, and the response can be instant. ProjectNet provides a central online meeting place for partners, including designers, architects, subcontractors, and developers.

Partners in each collaborative commerce type have different relationships and interactions so they might have different ethical issues. Here, let’s focus on a discussion of the first type of collaborative commerce. In the following subsection, information and material flows of the first type of collaborative commerce will be discussed and an exploration of the characteristics of collaborative commerce will be given afterward.

Table 1. Five Types of Collaborative Commerce

<i>Collaborative Commerce Types</i>	<i>Commerce Patterns</i>	<i>Examples</i>
One to One (1-1)		– TSMC’s eFoundry (www.tsmc.com)
Many to One (N-1)		– GE’s TPN (www.tpn.geis.com) – Formosa Plastics Corporation (www.e-fpg.com.tw)
One to Many (1-N)		– Intel (www.intel.com) – Dell Online Premier (www.dell.com) – Cisco’s CCO (www.cisco.com)
Many to Many (N-N)		– ChemConnect (www.ChemConnect.com) – Covisint (www.Covisint.com) – e2open (www.e2open.com)
Collaborative Cooperation		– Webcor Builder’s ProjectNet (www.Webcor.com) – Sun Microsystems (Sun 2001) – NiceShipping (www.NiceShipping.com)

Flows of Collaborative Commerce

As mentioned before, the one-to-one type can be extended to a supply chain. In a typical supply chain, there are many partners involved, such as suppliers, producers, distributors, retailers, and end users. However, here we limit our attention to three partners: producer, first-tier buyer, and second-tier buyer, as examples for our discussion.

As shown in *Figure 1*, after Producer receives materials or other items from various suppliers, Producer performs production activities. When the products or goods are ready, they are delivered to First-Tier Buyer (FTB) or directly to Second-Tier Buyer (STB). The sequence of material flows among partners is listed as follows:

- (1) Producer receives subassemblies, materials, indirect materials, and facilities from upstream suppliers or vendors.
- (2) Producer is engaged in production activities in order to produce goods.
- (3) Producer delivers goods to buyers either FTB (3a) or STB (3b).
- (4) In the case of (3a), FTB delivers goods to STB.
- (5) If STB is not satisfied with the goods, he can return the goods back to FTB (5a) or Producer (5b) directly.

Under an electronic commerce environment, the information flows among Producer, First-Tier Buyer, and Second-Tier Buyer are done electronically through platforms. The platform can be a portal, marketplace, or other forms, and it can serve as various functions such as marketing, sales, design and/or production information release, and so on. As shown in *Figure 2*, there is a

Figure 1. Material Flows Among Partners

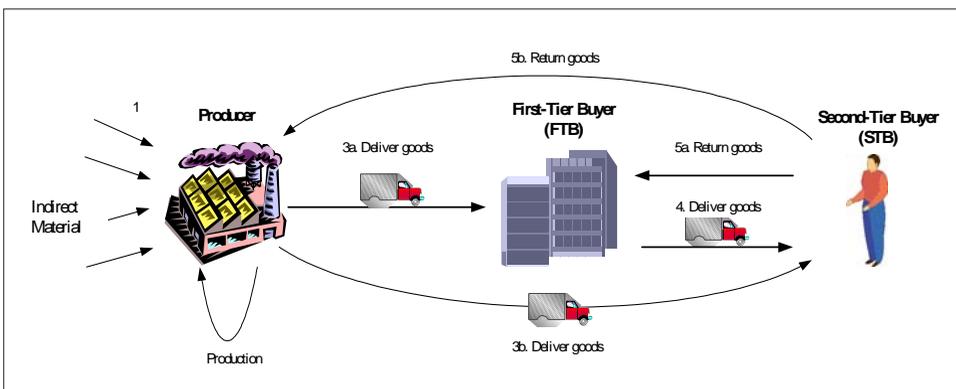
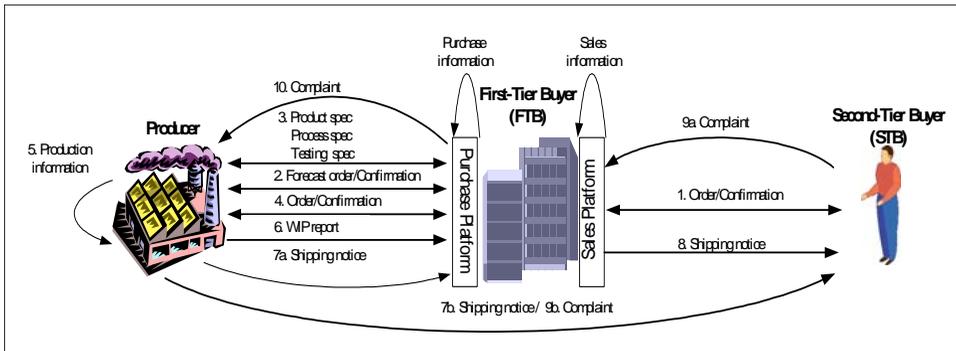


Figure 2. Information Flows Among Partners



typical information flow among Producer, FTB, and STB, and the illustration is listed as follows:

- (1) STB sends orders to FTB, and FTB confirms message to STB after he checks with his back-end systems.
- (2) STB releases the forecast order to Producer, then Producer confirms the forecast order when he is OK with it.
- (3) FTB sends specifications of products, process, and testing to Producer.
- (4) FTB releases order to Producer, and Producer confirms the order.
- (5) Producer generates production information during production.
- (6) Producer sends the WIP report periodically to FTB during production.
- (7) (a) Producer sends shipping notice to FTB after production has completed.
(b) Producer sends shipping notice to STB directly.
- (8) In the case of (7a), FTB sends shipping notice to STB.
- (9) When STB finds problems with product, STB can feed back the information to FTB (9a) or Producer (9b) directly.
- (10) After the case of (9a), FTB feeds back the complaint information to Producer.

Characteristics of Collaborative Commerce

Under an electronic collaborative commerce environment, in contrast with traditional commerce, there are three characteristics, namely, system dominant, digital information intensive, and partnership dependent. These characteristics are discussed as follows:

- (1) *System dominant*: In a commerce transaction between two parties, a transaction involves planning, execution, and control upon an infrastructure of information processing, storage, and communication. Traditionally, these operations are done manually and mechanically. However, after information technologies such as computers, networks, databases, the Web, application systems, etc., emerged in the last two decades, these operations are done electronically with systems built with an intensive interface between hardware and software. For example, in order management, order planning, receiving, allocating, processing, fulfilling, tracking, shipping, and billing could be done in systems which involve internal applications, such as enterprise resource planning (ERP) and supply chain management (SCM), and external applications, such as B2B and B2C systems, with all kinds of information infrastructure, such as communication networks, servers, computers, and database systems. Practically all operations can be performed systematically and automatically. Under such a circumstance, the system plays a dominant role. The success of an operation is strictly geared with the quality of the system.
- (2) *Digital information intensive*: Under an e-commerce environment, most information is digital and sometimes products are digital too. When information becomes digital, it has the following characteristics: easy processing and accessibility, instant and global communication, and transparency. People could take advantage of its digital form to manipulate, utilize, and convert it further and further in order to create more value.
- (3) *Partnership dependent*: In order to win the competition under an e-commerce environment, collaboration within the partnership is very essential. Under a collaboration agreement, each party could share resources with another party. Collaborative activities can be design, order fulfillment, production, sales, marketing, logistics, etc. In the electronic collaborative commerce environment, participant companies create public processes, working with their own private processes for various activities and with an electronic platform to share resources.

With the above three characteristics, in ordinary practices, participant companies and people will enjoy the business collaboration in order to win at business competition; however, on the other hand, it might turn out to be a big disaster when a flaw occurs in the system either intentionally or unintentionally. This damage will spread wider and quicker, and this is also due to the collaboration. In a later section, we will discuss more about the effects of intentional or ethical flaws.

Ethical Issues in Business

Ethics is two things, referring to well-based standards of right and wrong that prescribe what humans ought to do, usually in terms of rights, obligations, benefits to society, fairness, or specific virtue, and referring to the study and development of one's ethical standards. Ethics also means the continuous effort of studying our own moral beliefs and our moral conduct and striving to ensure that we, and the institutions we help to shape, live up to standards that are reasonable and solidly-based (www.scu.edu/ethics/practicing/decision/whatisethics.html).

The word *ethics* comes from the Greek word *ethos*, meaning character or customs (Solomon, 1984). Today, the word *ethos* refers to the distinguishing disposition, character, or attitude of a specific people, culture, or group. According to the *American Heritage Dictionary*, ethics is defined as (1) the study of the general nature of morals and of specific moral choices, and (2) the rules or standards governing the conduct of the members of a profession. One of the differences between an ordinary decision and an ethical one relates to the amount of emphasis placed on the person's values when the decision is being made. That is, the person's value standard plays an important role in the decision-making process.

Ethical problems are truly a managerial dilemma because they represent a conflict between an organization's economic performance (measured by revenue, cost, and profits) and its social performance (stated in terms of obligations to persons both within and outside the organization; Hosmer, 1991). These ethical dilemmas include environmental protection, decisions on the price of the products, employment/layoff of the labor forces, etc. Hence, a sound decision based on the ethical assessments on the various issues will guide the company with steady growth and good company image from the social point of view.

A business is defined as any organization whose objective is to provide goods or services. Most people would agree that "to survive" is one of the important aspects for a business. Hence, to survive, businesses must make profits and also balance their desires for profits against the needs and desires of society. Good ethics will be associated with good business. Furthermore, the definitions of business ethics usually relate to rules, standards, and moral principles as to what is right or wrong in specific situations. One of the definitions of business ethics comprises principles and standards that guide behaviors in the world of business (Ferrell, Fraedrich, & Ferrell, 2002). Ferrell et al. also classified business ethical issues into four major categories in relation to the business operations, namely, (1) conflict of interest, (2) honesty and fairness, (3) communications, and (4) technology. These four categories include other related business issues in various aspects of the business operation. These issues may not be all-inclusive

or mutually exclusive. However, they do provide an overview of some major ethical issues that the business decision-makers face. *Table 2* shows the four major business ethics issues identified.

With the advancement of information technology, the ethical issues that relate to the business operation have also become important. Mason (1995) pointed out four information ethical issues in the Information Age; they are privacy, accuracy, property, and accessibility (PAPA). The privacy issue is that a company should decide when, what, and how the company's personal information can or cannot be revealed to others. The accuracy issue, on the other hand, is who should be responsible for the accuracy and inaccuracy of the company's information and how to deal with damage due to this error and the consequences. Conger, Loch, and Helft (1995) classified information ethics into five categories: (1) ownership, (2) accessibility, (3) privacy, (4) responsibility, and (5) motivation. The motivation category includes rights for the development of the computer and related hardware and software.

Table 2. Four Major Business Ethics Issues

<i>Major Business Ethics Issues</i>	<i>Explanation</i>	<i>Other Related Issues</i>
Conflict of interest	An individual must choose whether to advance his or her own interest, those of the organization, or those of some other groups.	Bribery, Personal payment, Gifts, Special favor, and Kickback
Honesty and Fairness	Honesty refers to truthfulness, integrity, and trustworthiness. Fairness is the quality of being just, equitable, and impartial.	Negotiation, Employee discipline, Drug and alcohol abuse and testing, Inside trading, Antitrust issues, Workplace health and safety, and Whistle blowing
Communications	Communication refers to the transmission of advertising information and the sharing of meaning.	False, Lying, Abuse and deceptive advertising, Labeling, and Ambiguous statement
Technology	Technology and numerous advances made in the Internet and other forms of electronic communication.	Monitoring of employee use of available technology, Consumer privacy, Site development and online marketing, and Legal protection of intellectual properties

In the next section we will discuss the error model of ethics, or the ethical failure model. This is an analogy of the quality error, or quality failure, from the viewpoint of quality control and the associated causes and effects.

Ethical Failure Model for Collaborative Commerce

Ethics and quality share many things in common. They both involve norms and standards. On one hand, ethics is set of norms for human behavior; it is a system of moral codes in a society, providing people criteria for judging right and wrong in their motivations or behaviors (Frankena, 1963). On the other hand, quality is often defined as the overall features and characteristics of products and services that possess the capability to satisfy the specifications or potential desires of the customers (ISO 8042). Consequently it also relies heavily on norms and standards for accepting or rejecting a service or a product.

Traditionally, quality refers to characteristics of physical products and manufacturing processes. However, with the fast and widespread emergence of service industries, the scope of quality is consequently broadened from “little q” to “big Q.” Hence, the quality in its broad sense covers not only all products, goods, and services, but also all the processes including manufacturing, supporting, and all other business processes.

An ethical failure is often referred to as the failure to meet moral codes, or the nonconformance to social norms. To a certain extent, an ethical failure in the business environment can be considered as an operation failure in the business process due to human causes. Therefore, it is quite appropriate to compare ethical failures to quality failures in the broad sense. It is with this understanding that the ethical practice in the business environment, or collaborative commerce in particular, shall be discussed from a quality perspective.

Feigenbaum (1983) classifies the factors influencing quality into technical factors and human factors; he further points out that the human factors outweigh the technical factors. In a quality process, operation failures are categorized into technique failures, inadvertent failures, and conscious failures (Juran & Gryna, 1993).

The technique failures are those caused by operators who lack certain essential techniques, skills, or knowledge needed to prevent the failure from happening. This type of failures bears the features of unintentional, specific, consistent, and/or unavoidable. The inadvertent failures refer to those which operators are unable to avoid because of human inability to maintain consistent concentration.

This type of failure is characterized by being unintentional, unwitting, and unpredictable. However, the conscious failures are those which bear the evidence of being witting, intentional, and persistent.

Taking the nature of ethical failures into consideration, the ethical failures certainly fit very well into the category of conscious failures, which is featured as being witting in the sense that at the time of encountering a failure, the person is aware of it. In other times, an ethical failure is the result of his/her deliberate intention; moreover, the person often intends to keep the failure up.

While technique failures are usually not within the scope controllable by the operator, they are not considered as ethical failures. On the other hand, considering the fact that inadvertent failures are somehow within the influence of the person involved and also that commitment for excellence is one of the 10 basic elements of universal ethics, these inadvertent failures cannot be totally excluded from ethical failure. We will therefore refer to inadvertent failures as weak ethical failures, compared to conscious failures as strong ethical failures.

In summary, ethical failure can be considered as a very specific type of quality failure caused by a human being under a conscious state. Naturally, a failure model developed from the quality point of view is equally applicable to ethical failures.

The system involved in the development, maintenance, and improvement of quality is most often modeled in terms of the IPO (input process output) concept. *Figure 3* represents a typical quality control system, where the standard and the control feedback loops are shown in addition to the conventional components such as input, process, and output. It is to be noted that besides the “inputs,” such as material, information, etc., the “process” is the area where failures are most likely to originate. Subject to the major causes of failures, the process can be identified as system dominant, time dominant, information dominant, or operator

Figure 3. A Typical Quality Control System

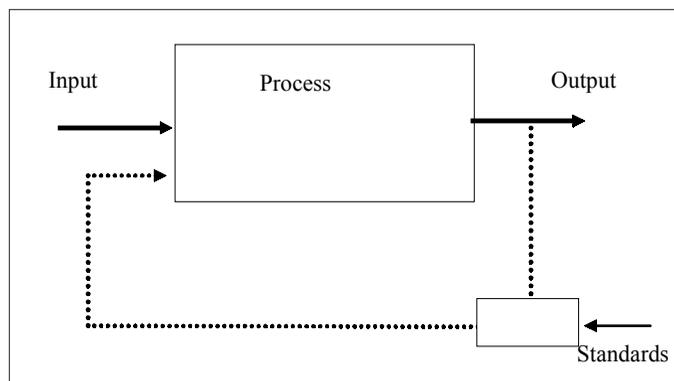
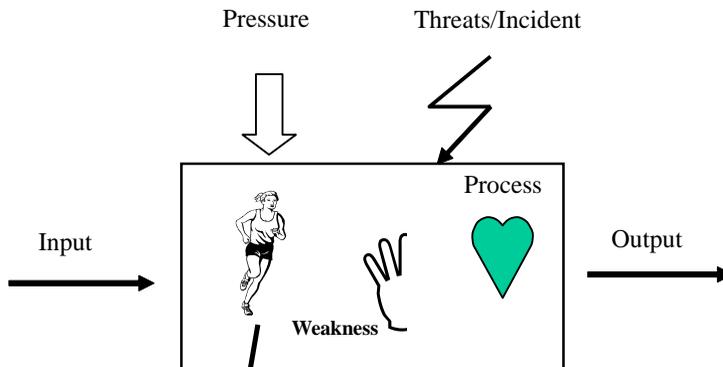


Figure 4. A Failure Model for an Operator-Dominant System



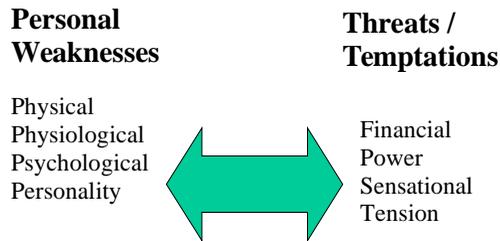
dominant. In general, ethical failures are more likely to occur in an operator-dominant process.

The operator-dominant concept refers to the scenarios where skill and knacks possessed by an operator are considered as the major contributing factors to the quality of the product or process. However, it is to be noted that the operator has, in addition to the skill aspect, also physical, physiological, and psychological aspects. While the skill aspect contributes to technique failures, physical and physiological aspects may result in inadvertent failures, with the psychological aspect leading to conscious failures. Although the skill, physical, and physiological aspects bear a certain degree of association with weak ethical failures, it is the psychological aspect that plays the most substantial role in strong ethical failures.

Figure 4 represents a failure model for an operator-dominant system. In this model, a failure can occur only when the weaknesses or defects, in quality terminology of the system directly encounter the threats coming from the environments or from within, triggered by any single incident. In Figure 4, while the hand represents the skill aspects of an operator, the whole body stands for the physical and physiological aspects, and the heart stands for the psychological aspects. On the other hand, the darkened plate above the system represents the long-term threats, and the double bent arrow stands for the short-term threats, or incidents. Where a failure occurs, the system often reveals some sort of weakness in it and also is characterized by being under certain kinds of threats.

The encounters of weaknesses and threats can occur at the individual level as well as the corporate level, as shown in Figure 5 and Figure 6, respectively. Most serious of all, ethical failures are almost inevitable whenever conflicts prevail in both the individual and corporate levels, as shown in Figure 7.

Figure 5. Weakness/Threats Encounters at Individual Level



The weaknesses at the individual level include the following aspects:

- (1) *Physical weaknesses*: those associated with structural disability, physical disorder, injury, fracture, or other weakness due to size, weight, appearance, etc.
- (2) *Physiological weaknesses*: disease, physiological disorder, physiological stress, restlessness, recklessness, slow neural response, or other weaknesses due to bio-clock, etc.
- (3) *Psychological weaknesses*: mental stress, emotion, EQ, IQ, etc.
- (4) *Personality weakness*: pride, sloppiness, perfectionism, workaholic, or other weaknesses in character, and/or interpersonal skill/relationship.

The threats or temptations at the individual level include the following four aspects:

- (1) *Financial*: greediness, bad debts, tie-ups, being in a financial strait, non-receivables, and financial pressures.
- (2) *Self-esteem*: disrespect, security crisis, power thirst, and self-actualization.

Figure 6. Weakness/Threats Encounters at Corporate Level

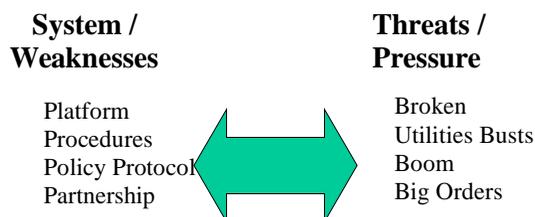
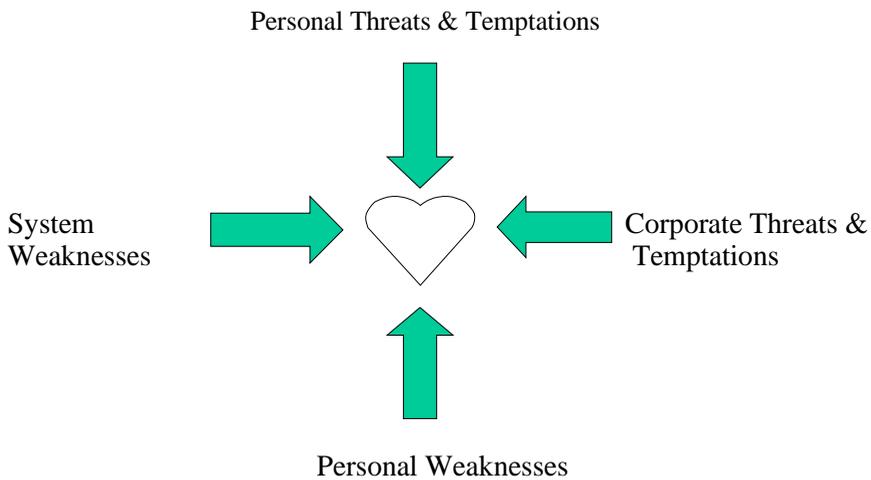


Figure 7. *Quality/Ethical Failures Upon Conflicts*



- (3) *Tension*: social, family, marriage, workplace, peer pressure, job layoff, perfectionism, and Monday-syndrome.
- (4) *Sensational*: sexual lust, drug addicts, and other addicts.

At the corporate level, in collaborative commerce (CC), the types of weaknesses a business system can have include the following five defects:

- (1) *Platform defects*: software program bugs, built-in bugs, hardware security, hardware reliability, software reliability, system compatibility, hardware setup, and interface.
- (2) *Procedure defects*: transaction procedures, system operation procedures, and test procedures.
- (3) *Policy defects*: mission, vision, objective, policy CC-specific, strategies, value, culture, and ethical codes.
- (4) *Protocol defects*: contracts/agreements in communication, operation, commercial, technical matters, intellectual property rights, business segmentation, and market segmentation.
- (5) *Partnership defects*: divisional and corporate level, mutual understanding, mutual trust, mutual commitment, and mutual acceptance.

Ethical Issues in Collaborative Commerce

As technology in general and the Internet in particular become a more important part of how virtually all companies do business, many are finding themselves faced with new ethical dilemmas and problems. These dilemmas might be (1) sharing customer information on the Internet; (2) releasing the customer list for sales information, which may violate the privacy agreement between the companies; (3) advertising the benefits of the system with ambiguous or lying statements, etc.; and (4) using the Internet or Web technologies, such as cookies or Web bugs, to collect customers' movements on a Web site. These companies are curious about just what limits there should be on how online businesses use the information they gather about their customers. And what responsibility do the companies have to publicly disclose their data-mining practices and the searching or monitoring results?

A good example of the ethical issues in collaborative commerce is the case of a third-party logistics company. The company has the capabilities for each customer's warehouse storage plan. Two competing customers are selling the same products (e.g., sportswear, shoes, shirts, etc.); hence, the sales and cost information for each customer is very critical and sensitive. However, each customer can access his own warehouse database and check the status of the inventory level through the Internet. Also, they can issue shipping orders to the warehouse for the benefit (time and efficiency) of the company's optimum operation plan. Hence, the warehouse operation and the overall logistics design for each customer compose a so-called "tailor-made" logistics system. For this third-party logistics company, the information is private for each customer and can't be revealed to another competitor.

Another example is the case in the music industry. The customers can pay a price (say, \$0.90 per song) to a computer company to download the specific song without buying the whole album. This company also offers a software tool to help the users in organizing their collected songs and then storing them on a CD. This reproduction of the CD is only for personal use. The computer company then pays the royalty fee to the music production company (e.g., Sony, EMI, etc.). Hence, these three parties with the mutual agreements can share the use and reproduction of the music. However, some unethical behaviors are not like this case, such as the previous Napster's peer-to-peer case.

Table 3 shows the potential ethical issues in collaborative commerce that can be found at various levels, from the corporate level to the operational level. These issues were collected and analyzed by categories based on business ethics and information ethics issues that were closely related to collaborative commerce.

Table 3. Potential Ethical Issues in Collaborative Commerce

Potential Ethical Issues	Explanation
Misuse of proprietary information	Disclosure to the unauthorized third party (or parties); Utilization of information beyond the purpose agreed upon.
Improper gathering of competitors' information	Gather information from competitors, first and second tier counterparts.
Unfaithful relationship with counterparts	Maintain unfaithful relationships with its competitors, suppliers, and customers.
Deficient product liability and safety	Provide with wrong products either physical products or system and software.
Joint Antitrust issue	Join with other companies to form the dominant system providers or force out others to come into the business.
Falsified information in book and record	Provide falsified information for the companies in business.

The examples of the unfaithful relationship with counterparts can be found in: (1) insufficient disclosure of business trends and perspectives, (2) intrusion on the other party's business territory, (3) alliance with counterpart's competition without seeking prior consent, etc. Cases of deficient product liability and safety are: (1) insufficient training for system operation, (2) insufficient disclosure of system weakness, (3) inadequate maintenance of system, etc. These examples are not limited to the current technology; they can be found and generated elsewhere and may not be predicted in advance.

The best way to maintain the competence and growth of the business operation for a company is it should have good practices for the various kinds of ethical issues. To encourage ethical behaviors, the company must be responsible for developing an ethics program for preventing misconduct. This program should provide employee training which includes understanding of a code of ethics, identification of common ethical issues, methods for employees to report misconduct, and a provision for monitoring and enforcing the program.

Conclusions

In this chapter, ethical issues have been identified to be associated with the concept of ethical failures, and a failure model has been derived from the quality point of view. Thus ethical issues derived from quality-related issues are judged to be equally applicable to ethical failures. For the development of the failure

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model, ethical failures based on weaknesses and threats at the individual and corporate levels have been identified.

For collaborative commerce, five collaborative types have been identified — one to one, one to many, many to one, many to many, and collaborative cooperation — from the business collaboration viewpoint of B2B commerce. To demonstrate the flows of collaborative commerce, a three-partner model — producer, first-tier buyer, and second-tier buyer — has been used as an example. For the characteristics of collaborative commerce, three characteristics, namely, system dominant, digital information intensive, and partnership dependent, have been identified. Furthermore, in the practice of business collaboration, it might turn out to be a big problem when a flaw occurs in the system either intentionally or unintentionally. This resulting damage could spread wider and quicker, and the effects of intentional or ethical flaws would lead to ethical issues in collaborative commerce.

Also, in this chapter, four major business ethics issues and six potential ethical issues in collaborative commerce have been identified and delineated.

In summary, a failure model has been developed for collaborative commerce. The model uses the concept of ethical failures to take up ethical issues from the quality point of view. This is a new approach for the discussion of ethical issues in collaborative commerce. It is recommended that more work be done to make this approach more fruitful.

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* * *

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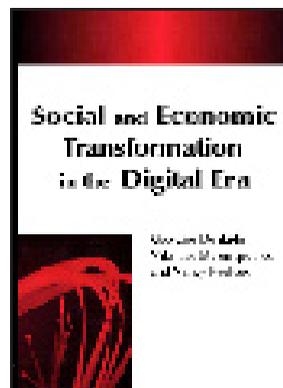
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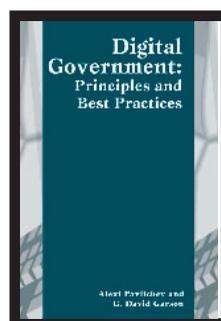
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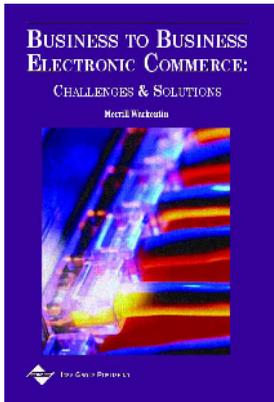
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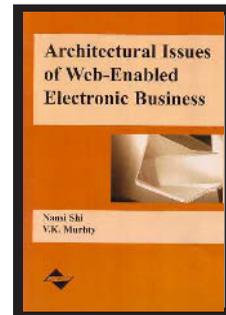
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