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Enabling supply chain integration using Internet technologies
Guest Editor: Dr Ronan McIvor

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Abstracts & keywords

The holonic enterprise: a model for Internet-enabled global manufacturing supply chain and workflow management

Mihaela Ulieru, Robert W. Brennan and Scott S. Walker

Keywords Internet, Supply chain, Artificial intelligence

Merges the latest results obtained by the holonic manufacturing systems (HMS) consortium with the latest developed standards for platform interoperability released by the Foundation for Intelligent Physical Agents (FIPA) to propose a novel e-business model: the holonic e-enterprise (HE). The HE extends both the HMS and FIPA models. On one side it extends the holonic manufacturing paradigm with one top level, the inter-enterprise one. On the other side it extends the multi-agent system (MAS) paradigm to the hardware (physical machine) level.

Supply chain modelling – a co-ordination approach

Zhengping Li, Arun Kumar and Yan Guan Lim

Keywords Supply chain, Modelling, Co-ordination, Integration

One of the typical issues in supply chain management (SCM) implementation is how to capture the complexities of supply chains. This paper reviews the existing supply chain modelling methods, and identifies the limitations of current methods. Based on these, a novel co-ordinated supply chain modelling approach is proposed to capture the complexity of supply chains from the views of scenario, interdependency, process and information. The proposed method is comprehensive, inclusive and aims to capture the complexities of a supply chain, align supply chain processes, and provide the basis for supply chain integration.

Enterprise integration: creating competitive capabilities

Ashley Braganza

Keywords Integration, Internet, Supply-chain management

For manufacturing firms, the concept of integration is hardly novel. The Total Quality, JIT, and supply chain management movements required improved internal and external coordination. While these movements centred on the manufacturing function, research suggests that integration of several functions at different organisational levels achieve above average financial and performance results. However, studies show enterprise integration is associated with many problems; at the root of these is a fundamental assumption: that all enterprise integration initiatives are equally important. Challenges this assumption. Argues that enterprise initiatives differ by their purpose; and proposes a framework for typifying enterprise integration initiatives that is based on the capabilities developed for the organisation. Four types of enterprise initiatives are identified. Illustrates each type with organisational examples. Discusses the managerial implications.

Application of established and emerging B2B e-commerce technologies: Australian empirical evidence

Damien Power

Keywords Internet, Electronic data interchange, Australia, Supply-chain management

Draws on data collected from 553 Australian companies and focuses on differences in the adoption of established (e.g. EDI) and emerging (e.g. the Internet) technologies for the management of supply chains. Overall, the use and adoption of existing technologies can be characterised as restricted, apparently costly, and perceived to be limited in terms of potential benefit. On the other hand, adoption and use of emerging technologies such as the Internet would appear not to be suffering from these traditional restrictions. The limitation of EDI to large companies is not evident in the use and adoption of the Internet, neither is the limitation on use at the manufacturing end of the supply chain. Concludes that there is evidence that the adoption of emerging Internet-based technologies for the management of supply chains does not appear to be subject to many of these constraints. However, it is not clear whether this ease of adoption will mean that the benefits will also flow as easily to these companies.

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XML-based supply chain integration: a case study

Juha-Miikka Nurmilaakso, Jari Kettunen and Ilkka Seilonen

Keywords Supply chain, Integration, Computer languages, Evaluation

This paper describes experiences gained from the implementation and evaluation of an XML-based integration system in a real case. The prototype was designed to support electronic data exchange in a supply chain. The purpose of the prototype was to study the properties of the integration system from both a development and usage perspective. In particular, the study outlined how and in which circumstances XML facilitates supply chain integration. EDI provided a point of comparison. This information is useful both for the developers and users of integration systems.

Collaborative supply chain planning using electronic marketplaces

Martin Rudberg, Niklas Klingenberg and Kristoffer Kronhamn

Keywords Supply-chain management, Production planning, Internet, Business development, Business-to-business marketing

The purpose of this paper is to show how the functionality of electronic marketplaces can facilitate collaborative supply chain planning. Supply chain planning processes are identified and analysed using a supply chain management focus. The paper also gives a brief introduction to a framework for supply chain management and to the typical structure of electronic marketplaces. Furthermore, three collaborative supply chain planning scenarios are defined, and it is shown how collaborative supply chain planning typically could be implemented on an electronic marketplace by the means of a Web-based demonstration. As such, the paper shows how electronic marketplaces can be used to enable supply chain integration.

Guest editorial

About the Guest Editor
Ronan McIvor is a Senior Lecturer within the Faculty of Business and Management at the University of Ulster. He has extensive teaching and research experience in information systems and supply chain management. He is currently involved in a number of projects including the application of knowledge-based systems techniques to supply chain management problems, outsourcing and early supplier involvement (ESI) in new product development. In particular, he has been actively involved in the development of knowledge-based and decision support systems to assist in a variety of business applications including a tendering and estimating system for use in an aerial surveys company and an advice tool for public sector bodies on European procurement legislation.

The increasing importance of innovative information communication technology (ICT) for economies and societies has been attracting considerable attention both from academia and practitioners. In the last number of decades ICTs have deeply affected the way business is performed and the way that organisations compete. In particular, the advance of the Internet, with its vast range of potential services and applications, has led to a transformation of corporate strategy since the middle of the 1990s, as reflected in the increasingly common use of terms such as industry convergence, virtual corporations and electronic commerce. The rise of the Internet and electronic commerce has created one of the most challenging environments for innovative behaviour. The connectivity associated with the Internet has the potential to bring together an industry's customers and suppliers in a unified and economically perfect marketplace. The significant difference between the Internet and other forms of computer networks is that the open standard allows seamless integration between many incompatible computer applications and legacy systems. With the advent of Internet-enabled communications, it is now possible for an organisation to establish links with other organisations at significantly lower costs than with previous technologies. For example, an organisation offering a range of products and services can now create an electronic catalogue on its Web site in order to achieve global reach. Innovations in Internet technologies such as intranets and extranets are critical in co-ordinating the activities of cross-functional teams across organisational boundaries. Electronic commerce can reduce the costs associated with closely integrating buyers and suppliers and through electronic networks organisations can achieve greater integration at the buyer-supplier interface. Electronic commerce can reduce an organisation's costs in a number of ways. It reduces procurement costs, both by making it easier to find the lowest priced supplier and through efficiency gains. It is much less costly to place an order on-line, and there are likely to be fewer errors in orders and invoicing. Also these benefits are not confined to large organisations, Internet technologies and electronic commerce provide a vehicle for enabling SMEs to behave in a more creative and innovative way. The exploitation of Internet technologies provides an enormous opportunity for SMEs to access the global supply networks of larger firms.

Although the potential of the Internet to provide greater levels of integration is widely recognised, in practice it can be quite difficult to achieve. Even in the case of Internet-enabled commerce incompatibility of systems and agreed standards for transactions can still pose significant challenges. Also, with the implementation of Internet technologies it is very difficult to eliminate fully the human element. However, due to the constant cost pressures on companies, it is likely that companies will attempt to exploit more fully the potential of Internet technologies at the buyer-supplier interface. Technological advances have created new opportunities in integration and management of all aspects of supply chains, including, for example, procurement, manufacturing, inventory management, integrated product development and logistics. In fact, organisations have begun to embrace the notion that competitive advantage is a function of supply chain efficiency and effectiveness. Suppliers are a significant source of innovation and provide scope for differentiation. It is possible for organisations to integrate their suppliers in unique ways across organisational boundaries to obtain an advantage over their competitors. The exploitation of Internet technologies provides a vehicle to achieve this greater integration and create unique sources of leverage in the value chain. Effective implementation of electronic commerce to support inter-organisational relationships requires that electronic commerce be fully integrated into both the business architecture and technology infrastructure of both the customer and the supplier. However, there is still significant progress to be made before companies can achieve this level of integration at the buyer-supplier interface. This special issue seeks to provide insights and further inform the debate on the application of Internet technologies at the buyer-supplier interface.

Ronan McIvor

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The holonic enterprise: a model for Internet-enabled global manufacturing supply chain and workflow management

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Abstract
Merges the latest results obtained by the holonic manufacturing systems (HMS) consortium with the latest developed standards for platform interoperability released by the Foundation for Intelligent Physical Agents (FIPA) to propose a novel e-business model: the holonic e-enterprise (HE). The HE extends both the HMS and FIPA models. On one side it extends the holonic manufacturing paradigm with one top level, the inter-enterprise one. On the other side it extends the multi-agent system (MAS) paradigm to the hardware (physical machine) level.

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This paper builds on the results obtained over the past ten years by the members of the Intelligent Systems Group (ISG – http://isg.enme.ucalgary.ca) at the University of Calgary, under the leadership of Professor Douglas H. Norrie. Without his vision and continuous support, this work would not have been possible. Thank you, Doug, for being such an inspiring mentor to us all!

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Introduction

In the context of today's tremendous advances in information and networking technologies the World Wide Web (WWW) is enabling partnerships otherwise impossible in all areas of our life. The static, centralized, sequential, closed, over-the-wall models of the exclusively-competitive world are one-by-one replaced by dynamic distributed, parallel, open collaborative strategies calling for new organizational paradigms supporting globalization of all aspects of life (McHugh *et al.*, 1995). The race for success in the connected world is governed by the way enterprises are able to use the power of the novel information infrastructures that support dynamic clustering and service deployment in an open environment (Agentcities, 2002). Latest advances in distributed artificial intelligence have enabled software emulation of real-life communities as multi-agent systems (MAS). By cloning real-life entities (people, machines and organizations) as software agents connected via the Internet, a virtual society emerges in Cyberspace and the WWW becomes a dynamic environment through which agents move from place to place to deliver their services and eventually to compose them with the ones of other agents, just like people cooperate by exchanging services and/or putting together their competencies in a larger, more complex service.

Thus the WWW is today a dynamic service environment (DSE) information infrastructure that supports production and binds organizations together in the networked economy. In particular, production processes are information rich and the dynamics of the information infrastructure is the tool for carrying it out both at individual locales and across the global environment. The electronic linking implies that work matter (or critical parts of it) is being transferred across virtual locales via the DSE, which supports organizational information that, in turn, can mirror social organization.

The Holonic Enterprise (HE) has emerged as a business paradigm from the need for flexible open reconfigurable models able to emulate the market dynamics in the networked economy (McHugh *et al.*, 1995), which necessitates that strategies and relationships evolve over time, changing with the dynamic business environment.

We begin with an overview of the three main concepts used to develop our HE model: holonic systems, MAS, and the Internet. Next, the role that mediator agents play in holonic systems is described, along with various patterns of holonic collaboration. This leads to the description of the HE model and, finally, an illustrative example of how this model can be applied to a typical manufacturing enterprise.

Background

The holonic systems paradigm

The main idea of the HE model stems from the work of Koestler (1967). In his attempt to create a model for self-organization in biological systems, Koestler has identified structural patterns – namely that they form nested hierarchies of self-replicating structures, named holarchies. Koestler proposed the term "holon" to describe the elements of these systems. This term is a combination of the Greek word *holos*, meaning "whole", with the suffix *-on* meaning "part", as in prot*on* or neur*on*. This term reflects the tendencies of holons to act as autonomous entities, yet cooperating to form apparently self-organizing hierarchies of subsystems, such as the cell/tissue/organ/system hierarchy in biology (Christensen, 1994). Holons at several levels of resolution in the holarchy behave as autonomous wholes and yet as cooperative parts for achieving the goal of the holarchy. Within a holarchy, holons can belong to different clusters simultaneously, displaying rule-governed behavior. The rules define a system as a holon with an individuality of its own; they determine its invariant properties, its structural configuration and functional pattern. The duality autonomy-cooperation as main contradictory forces within a holarchy is balanced by the rules that define the functionality of such a system of semi-autonomous holons.

From a software engineering perspective, a holon, as a unit of composition retaining characteristic attributes of the whole system (holarchy), can be viewed as a class. Thus the object-oriented paradigm seemed suitable for modeling holarchies as software systems (Booch, 1994).

The multi-agent systems paradigm

In response to the need for modeling the complexity of interactions in large-scale distributed systems, agent technology has emerged as a paradigm for structuring, designing and building software systems that require complex interactions between autonomous distributed (software) components. While the object-oriented paradigm models systems focusing on the structural, static characteristics of their parts, which are defined through encapsulation and inheritance, the agent paradigm models systems focuses on the underlining dynamics defined by the interactions between their parts. In contrast to the passive way in which objects communicate by invoking methods in one another in a way controlled externally by the user (e.g. from a "main" program), agents are capable of initiating communication and deciding (like a human) when and how to respond to external stimuli (e.g. manifested on them as requests from other agents). From this perspective the agent paradigm extends the object paradigm in that agents can be regarded as proactive objects (Wooldridge, 2001) that have an internal mechanism which governs their behavior, enabling them to initiate action as well as respond to the outside environment in an autonomous way. With this in mind one can define:

- an intelligent agent as a software entity which exhibits, in some significant measure, autonomy, intelligence, and environmental awareness, and which interacts with its environment to achieve internal goals;
- a MAS as a software system in which program modules (the individual agents) are given autonomy and intelligence and an underlining coordination mechanism (implementing rules for collaboration, like for holarchies) which enables collaboration between such modules (agents) to attain system objectives.

A software representation of a holarchy thus appears natural as MAS, consisting of autonomous yet cooperative agents. From this perspective a MAS is regarded as a system of agents (software holons) which can cooperate to achieve a goal or objective. The MAS (software holarchy) defines the basic rules for cooperation of the agents (software holons) and thereby limits their autonomy. In this context, autonomy is defined as the capability of an entity (i.e. agent or holon) to create and control the execution of its own plans and/or strategies, while cooperation is the process whereby a set of entities develop mutually acceptable plans and execute them.

The common denominator between holonics and MAS as paradigms is obviously the focus on the dynamics of the interactions. However, in a MAS there is no pre-assigned condition that the interactions should be driven by cooperative forces, while in a holonic system this is a precondition for the existence of the holarchy *per se* (the glue that binds the holarchy together driving it towards the common goal). It is this "team-spirit" that characterizes a holarchy, in that all its component parts at all levels of resolution work together towards achieving the goal in an optimal manner. This "togetherness" drives the self-organizing power that configures all the sub-holons to optimize the interactions within the holarchy to reach the common goal with maximum efficiency. On the other side, in a MAS, agents may interact based on competitive rather than cooperative rules (e.g. electronic markets or other competitive/conflicting environments such as military scenarios; competing over resources or societal/political disputes, etc.) – which is excluded as a possibility in a holarchy.

The Internet

The MAS paradigm has challenged the software world and with it the world of information technologies through its ability to enable emulation in Cyberspace of real-world societies as virtual communities of agents. The marriage between MAS and the Internet has created a parallel world of information that "lives" in the Web universe emulating our games in all aspects of life, be they economic, financial, business, school or health-related, or even just-for-fun in computer games.

MAS enable cloning of real-life systems into autonomous software entities with a "life" of their own in the dynamic information environment offered by today's Cyberspace. The WWW connects by invisible links these entities through their virtual "clones" forming "societies" in which the virtual entities (mostly modeled as software agents) have their own "life" interacting with an autonomy of their own. When such virtual societies are driven towards a common purpose they cluster into collaborative holarchies (Ulieru, 2002).

Enterprises partially "cloned" as agents that interact over the Internet, can cluster as well into holarchies to form global virtual organizations. Two main enterprise-related paradigms have emerged supported by this technological development: the Web-centric enterprise and the virtual enterprise.

Unlike existing point solutions that focus on a single-department or activity product, such as data management or product-design-and-manufacturing, the Web-centric model (Hornberger, 2001) addresses product and process life-cycle management across the extended enterprise regarded as a global organization. At the core of the Web-centric enterprise model is the Internet-enabled software infrastructure acting as a worldwide open DSE. Such an integrated framework enables sharing of information, services and applications among suppliers, employees, partners and customers via:

- Deployment of automated, intelligent software services (e.g. Internet-enabled negotiations, financial transactions, advertising and bidding; order placement/delivery, etc.).
- Complex interactions between such services (e.g. compliance policies; argumentation and persuasion via complex conversation protocols, etc.).
- Dynamic discovery and composition of services to create new compound value added services (e.g. dynamic virtual clustering of synergetic partnerships of collaborative organizations aiming to achieve a common goal).

A virtual organization or company is one whose members are geographically apart, usually working by electronic linking via computers while appearing to others to be a single, unified organization with a real physical location. Within a virtual organization, work cannot be completed without support of an information technology infrastructure in linking the parts.

The virtual enterprise (VE) paradigm differs from the Web-centric paradigm in that a VE is a distinct organizational form, not just a property of any organization. Thus, Web-centric organizations that can use communications extensively, but not in a way critical in fulfilling the goal of the organization (e.g. a multinational corporation with dispersed parts being on the same satellite network whose use, however, is not critical for completing the production process) are not VE. In today's global economy in which enterprises put together their competitive advantage to leverage a higher purpose otherwise impossible to achieve, the VE is an appropriate model for strategic partnerships. Such a strategic partnership model calls for new perspectives on competition in the global open Internet-enabled economy.

The networked economy mandates the shift from industrial age, "brick-and-mortar" strategic thinking to an emphasis on new alliances and a rethinking of traditional partnerships. Alliances and partnerships can be formed in ways that increase value for all players. The concept of co-opetition (Brandenburger and Nalebuff, 1996) builds on the duality inherent in all relationships with respect to win-win and win-lose interactions. The success of most businesses is dependent on the success of others, yet they must compete to capture value created in the market and protect their own interests. The main issues to be addressed when developing a business strategy based on co-opetition are:

- Who are the players in the network and how can they collaborate to maximize value?
- Which relationships are complementary in nature – which companies can add value to what they provide?
- Which players are competitors, and are there mutually beneficial ways to create value?
- What can they do to sustain their competitive advantage over time?

Holonic collaboration

In this section, we discuss how the holonic paradigm supports collaborations of autonomous entities. This results in the basic holonic notion of autonomous and cooperative building blocks (i.e. holons) that are used to lay the foundation of the HE discussed in the next section.

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The mediator architecture

A system decomposition and analysis based on holonic principles naturally suggests a distributed software implementation, with autonomously executing cooperative entities as building blocks. As illustrated in Figure 1, the stable intermediate forms/holons of the system can be implemented at the lower levels by objects, at the medium level by agents, and at the higher levels by groups of agents, with these mapping decisions being application-specific. (Of course, these are only the software portions of the holons.) Also, holons should have an interface which is simple and cohesive, just like in object-oriented systems (Eliens, 2000) or any effective organizational structure, and which is itself a holon.

In the previous section we emphasized on the cooperative forces that drive the holons towards achieving the common purpose of the holarchy. How does one build agents and groups of agents which fulfill the holonic philosophy? (The third option, mapping holons into objects, is an almost trivial task that needs no discussion here.) The basic condition for holonic systems is that a holon is simultaneously a "whole" and a "part" of some other whole/holon. This means that holons may contain other lower level holons, and may themselves be contained in other higher level holons, resulting in a recursive architecture. The agents to be used to implement this holonic system will be considered independently executing processes on some computer/machine/device. In this case, if a one-to-one mapping of holon to agent is performed, it is much more difficult to implement an agent practically (than it is to conceptualize a holon) which is itself a component of a higher level agent and which also contains lower level agents.

Here, the concept of a mediator agent comes into play. The mediator will fulfill two main functions. First, it acts as the interface between the agents in the holon and between the agents outside the holon (i.e. acts as a type of facilitator); conceptually, it can be thought of as the agent that represents the holon. Second, it may broker and/or supervise the interactions between the sub-holons of that holon; this also allows the system architect to implement (and later update) a variety of forms of interaction easily and effectively, thereby fulfilling the need for flexibility and reconfigurability. Such a mediator as described can actually be considered a static mediator, and will exist primarily at the boundary of a homogeneous holon (such as an ordering holon in a supply chain example), as illustrated in Figure 2.

In manufacturing holarchies the mediator encapsulates the mechanism that clusters the holons into collaborative groups (Maturana and Norrie, 1996).

This type of mediator is a "dynamic mediator". In the case of interactions between heterogeneous holons, such as an order holon and various resource scheduling holons, ease of system design may be supported by employing a dynamic mediator agent to broker and/or supervise the

Figure 1
Multi-granular decomposition of holons in agents and objects

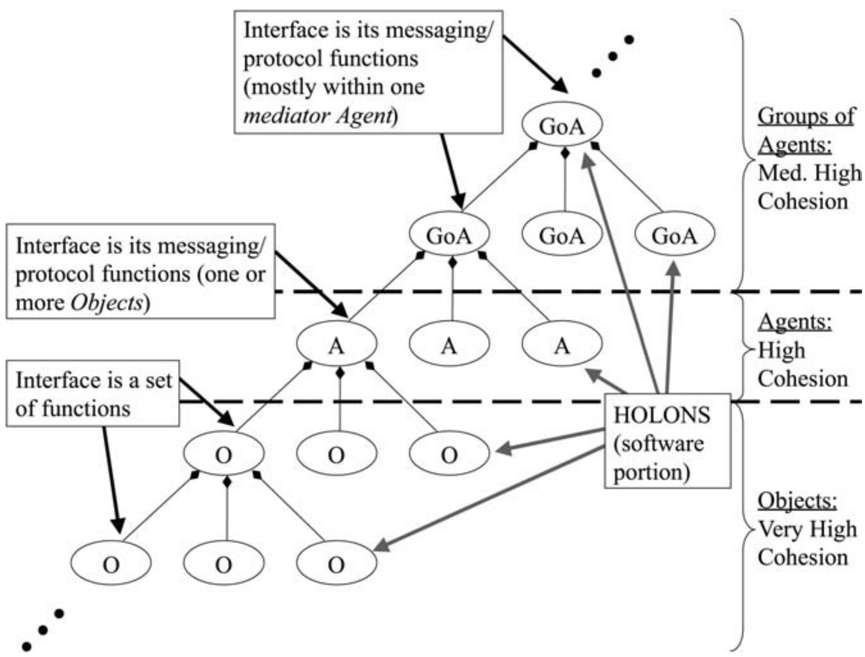
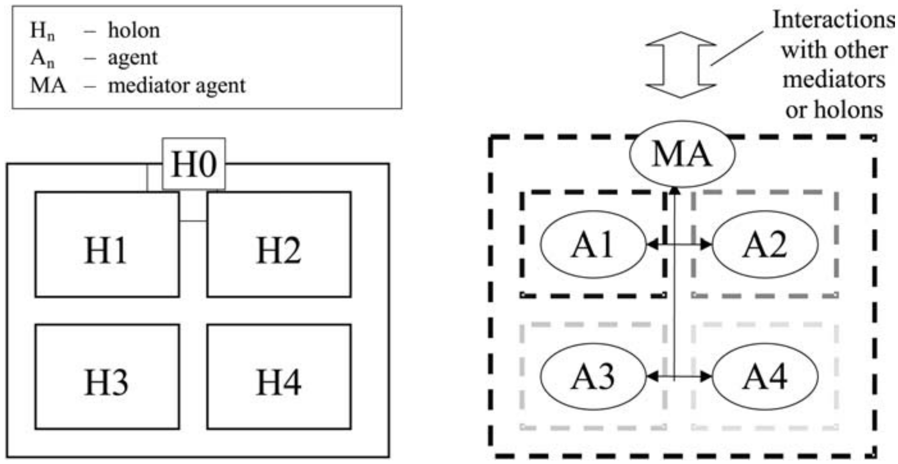


Figure 2
Mapping holonic systems in MAS via mediators



interactions within a group of holons/agents. These groups, or clusters, represent interactions to accomplish a specific task. These interactions can be called a "conversation", and the group of agents/ holons involved can be called a "dynamic virtual cluster" (dynamic because they form and then dissolve as tasks are initiated and then completed, and virtual because they represent a logical or functional decomposition of the system interactions, and not a structural grouping of system components). Dynamic mediators, dynamic virtual clusters, and conversations are all central concepts to the design of manufacturing holarchies (Zhang and Norrie, 1999).

The architectural structure in such holarchies follows the design principles for metamorphic architectures. For example, in Figure 3, physical manufacturing resources (e.g. milling machines, robots, etc.) at the machine level are represented by corresponding software agents (e.g. machine "m1" is represented by agent "1-1"). These agents may then be grouped dynamically at the enterprise level based on the current product line (e.g. using group technology methods). In order to execute specific orders, clones of these agents may now participate in dynamic virtual clusters as illustrated at the top of Figure 3.

In order to facilitate the dynamic virtual clustering process, a pattern of holonic collaboration is followed as is summarized in Figure 4.

Patterns of holonic collaboration

As an organizational paradigm (inspired by the self-organizing properties of natural systems), holonics models social organizations as nested clusters (holons) of sub-organizations (sub-holons) driven towards a common purpose by collaborative rules. The rules act as forces that coordinate interactions between sub-holons working together towards a common purpose. Of crucial importance is that rules ensure coordination with local environment, that is with the other holons and sub-holarchies.

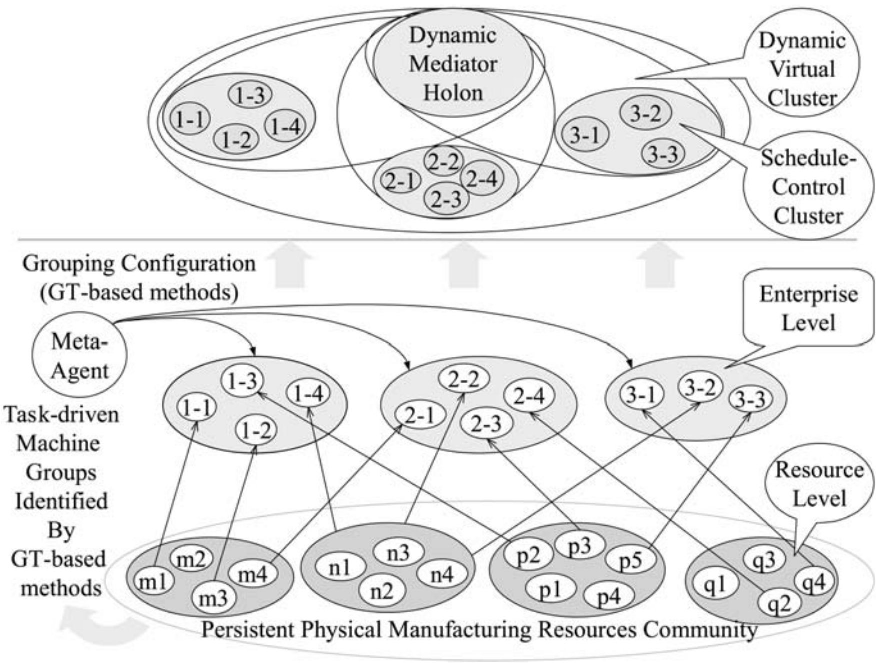
The HE paradigm emerges from the synergetic triad Holonics-MAS-Internet to provide a framework for information and resource management in global virtual organizations by modeling enterprise entities as software agents linked through the Internet. The rules for holons in a HE are co-opetition rules implemented as strategies for negotiation, collaboration, cooperation and other coordination mechanisms. Such rules define the patterns of holonic collaboration according to which the holarchy functions.

The MAS inhabits the environment of computers, controllers, and networks; as such, each agent is part of a holon. Its inputs are the machine's sensors, data from storage, and interactions or communications with other agents and with humans; its outputs are the physical control of machines, data to storage, and interactions or communications with other agents and with humans.

The flexible re-configurable architectural model in Figure 3 is enabled by the synergetic interaction of the following patterns that form the coordination backbone of a HE:

- *Dynamic virtual clustering*. This pattern is facilitated by the general layered architecture of the HE. Each resource consists of control execution (CE), execution control (EC), and execution (E) agents. Details of this machine level model will be described in further detail in the

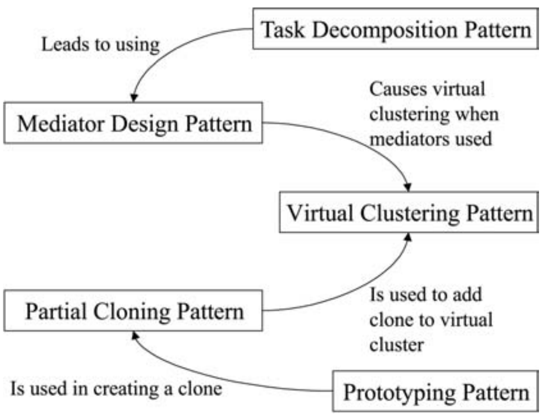
Figure 3
Mediator-based metamorphic architecture



next section. The dynamic virtual clustering pattern plays a crucial role in that it embeds the self-organizing properties of a HE. The main responsibility of this pattern is to configure the enterprise to minimize cost enabling for flexible, re-configurable structures. At all levels of the HE, task propagation occurs by a process of virtual cluster (or holarchy) formation.

- *Mediator design pattern*. The mechanisms supporting the decision-making process that creates and (re)-configures the dynamic virtual clusters of collaborative entities (eventually by adding/removing entities to/from the holarchy to ensure maximal synergy in accomplishing the goal of the HE) are contained in the mediator.
- *Partial cloning pattern*. This pattern defines which of the enterprise's characteristics (attributes and functionality) are abstracted into agents at each level when modeling the HE as a collaborative multi-agent system.

Figure 4
Patterns of holonic collaboration



Once the goal of the HE has been determined the mediator clusters the global distributed resources (cloned as agents by the partial cloning pattern) using the mechanisms implemented in the dynamic virtual clustering pattern, such that the goal can be achieved optimally. This is done through the task decomposition pattern (illustrated in Figure 5) that splits the goal into sub-tasks which are distributed across the available resources.

Task decomposition-distribution pattern

This pattern ensures the workflow coordination throughout the collaborative holarchy ensuring harmonious distribution among the participants the overall task assigned to the collaborative holon, at each level.

The main mechanisms by which this pattern works are:

- *task distribution among the cluster's entities* – outside-in view from the mediator "down" into each collaborative partner at that level; and
- *task deployment within each entity* – inside-out view, from the entity, regarded

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as a holon with distributed resources available to it for accomplishing the assigned task, to the mediator.

Both mechanisms call for appropriate negotiation strategies (Jennings *et al.*, 2001) to enable appropriate loading of each collaborative partner according to its available resources as well as deadline commitment and delay justification through appropriate argumentation and persuasion strategies. An excellent tool for inducing decentralization into the holonic collaboration is the institutionalized power (Jones and Sergot, 1996) that transfers complete responsibility regarding the "how" of the task's accomplishment to the entity to which the task was assigned once this entity has accepted the delivery conditions.

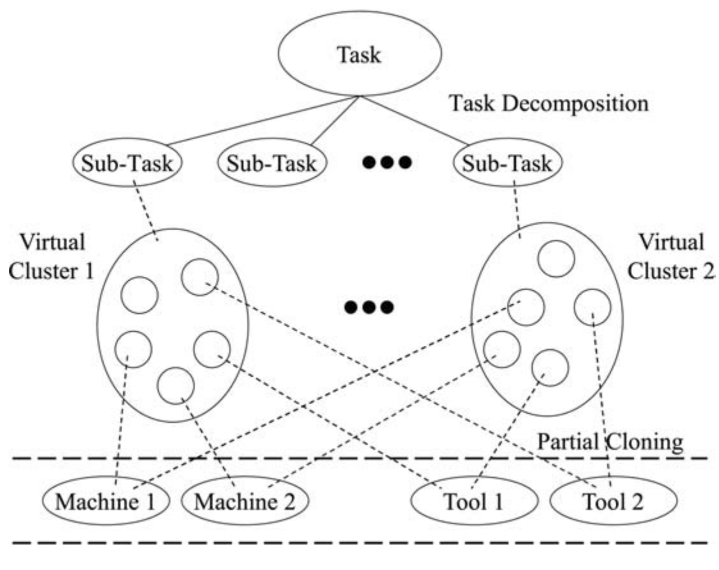
Propagation of the task decomposition-distribution pattern throughout the granular levels of the HE requires two kind of ontologies to enable 'inter-entity' communication, which define an ontology pattern.

Ontology pattern

This consists of two kind of ontologies:

1. "Peer-to-peer" communication within each level (that is "inter-agent" communication among entities that form a cluster).
2. "Inter-level" communication that enables deployment of tasks assigned at higher levels (by the mediator) on lower level clusters of resources as well as reporting (from the lower level to the higher) of emergency situations for which rescheduling/re-planning reconfiguration are required.

Figure 5
The task distribution pattern



The HE

The general HE model is illustrated in Figure 6. As can be seen in this figure, the HE is a holarchy of collaborative enterprises, where each enterprise is regarded as a holon and is modeled by a software agent with holonic properties, so that the software agent may be composed of other agents that behave in a similar way but perform different functions at lower levels of resolution. The flow of information and matter across the HE defines three levels of granularity:

1. the inter-enterprise level;
2. the intra-enterprise level; and
3. the machine level.

In this section, we describe the models used at each of these levels.

The inter-enterprise level

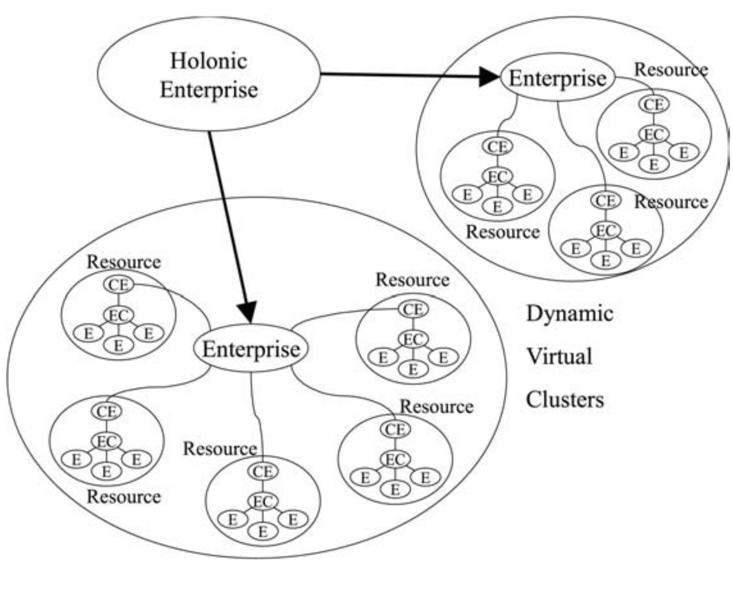
At this level, several holon-enterprises cluster into a collaborative holarchy to produce products or services. The clustering mechanisms embedded in the mediator support maximal synergy and efficiency.

Traditionally, especially in the manufacturing domain, this level was regarded as a mostly static chain of customers and suppliers through which the workflow and information was moving from the end customer who required the product to the end supplier who delivered it. The lag induced throughout the predetermined chain, linking suppliers with long-lasting relationships, was affecting the customer on one side through its inability to accommodate changes in product requirements; on the other side, through its supplier-centeredness that placed the supplier interests above the customer's when it came to timely delivery of products (Fox *et al.*, 1993). Taking advantage of the power of the Internet, the HE model endows the supply chain with flexibility and reconfiguration capabilities intrinsic in the collaborative holarchy paradigm shown in Figure 6. With each collaborative partner modeled as an agent that encapsulates those abstractions relevant to the particular cooperation, a dynamic virtual cluster (illustrated in Figure 3) emerges which can be configured on-line according to the collaborative goals. Such a dynamic collaborative holarchy can cope with unexpected disturbances (e.g. replace a collaborative partner who cannot deliver within the deadline) through on-line reconfiguration of the open system it represents. It provides on-line order distribution across the available partners as well as deployment mechanisms that ensure real-time order error reporting and on-demand order tracking. Thus the static supplier-centered chain becomes a dynamic collaborative holarchy emerging around customer needs to bring together the best suppliers able to satisfy these needs in the best possible way.

The intra-enterprise level

Once each enterprise has undertaken responsibility for the assigned part of the work, it has to organize in turn its own internal resources to deliver on time according to the coordination requirements of the collaborative cluster. For example, in the manufacturing domain, planning and dynamic scheduling of resources at this level enable functional reconfiguration and flexibility via (re)selecting functional units, (re)assigning their locations, and (re)defining their interconnections (e.g. rerouting around a broken machine, changing the functions of a multi-functional machine). This is achieved through a replication of the dynamic virtual clustering mechanism, having now each resource within the enterprise cloned as an agent that abstracts those functional characteristics relevant to the specific task assigned by the collaborative holarchy to the partner. Reconfiguration of schedules to cope with new orders or unexpected disturbances (e.g. machine failure) is enabled through re-clustering of the agents representing the actual resources of the enterprise, as illustrated in Figure 5. The task assigned to each enterprise is distributed on its internal resources via the task deployment pattern, as follows. First the task is split into sub-tasks which can be assigned to clusters of resources belonging to each enterprise. The virtual communities of agents cloning the resources of each enterprise cluster around dynamic mediators generated around each sub-task. The holonic mediator acting at the inter-enterprise level, emulates production to find the optimal configuration of the resource clustering at the lower levels. The main criteria for resource (re)allocation when (re)configuring the schedules are related to cost minimization achieved via multi-criteria optimization.

Figure 6
The holonic enterprise



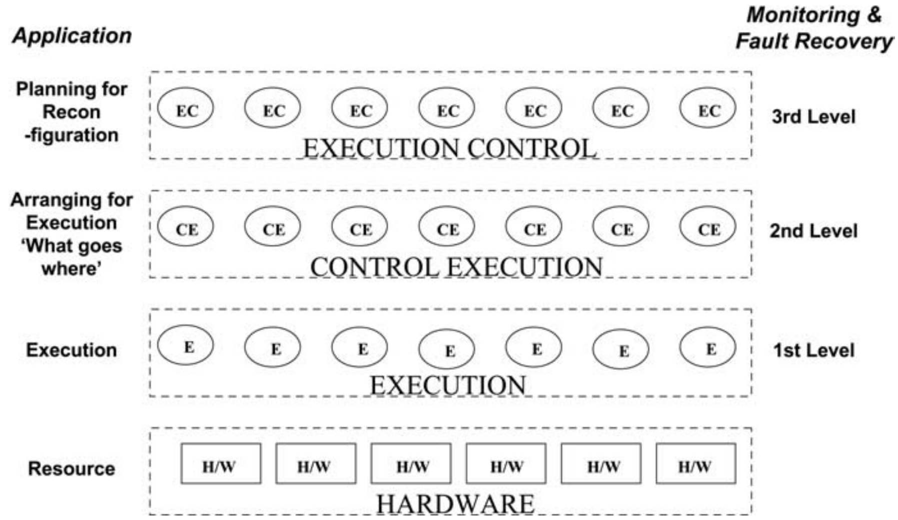
The machine level

In a manufacturing context, this level is concerned with the distributed control of the physical machines that actually perform the work. To enable agile manufacturing through the deployment of self-reconfiguring, intelligent distributed automation elements, each machine is cloned as an agent (Figure 5), which abstracts those parameters needed for the configuration of the holonic control system managing the distributed production.

Once resources are allocated to each sub-task and the production plan configured by the mediators at the inter- and intra-enterprise levels, the schedules of operations are deployed on each resource via the task deployment pattern. In order to decompose the control application management and fault monitoring and recovery tasks in this manner, a multi-layer holonic control architecture is used that consists of the four temporally decomposed layers illustrated in Figure 7: execution control (EC), control execution (CE), execution (E), and hardware (H/W). This architecture reflects the multiresolutional structure of the HE as well as the inter-level ontologies between the intra-enterprise and the resource management levels. As we move down the layers shown in this figure, time scales become shorter and real-time constraints change from soft to hard real-time; as well, the degree of agency decreases (i.e. higher agents are more sophisticated but slower, while lower agents are fast and light-weight). The EC layer is concerned with "high-level" planning issues such as for reconfiguration control. The CE layer is concerned with arranging for the distribution of applications across multiple resources. The E layer is concerned with the execution of the application. The H/W layer is the physical platform, or the resource being controlled.

Although they work at each level to manage the flow of information and materials within the HE, these patterns have specific particularities within each level of the collaborative holarchy. In the sequel, we will identify on a laboratory example these

Figure 7
Multi-layer machine level architecture



particularities and clearly define the policies and services supported by the patterns as well as the mechanisms that would enable their implementation within each level.

A manufacturing enterprise example

In order to illustrate the basic patterns of holonic collaboration within an HE, we focus on an example of a multi-national corporation that manufactures telephones in this section. Building products like telephones or answering machines involves the acquisition and integration of different components and materials, from various manufacturers and suppliers, thus providing a suitable example of a supply chain. For the sake of simplicity, it is assumed that telephones consist of a printed circuit board, a moulded case and transmitter-receiver equipment as components and cables as materials or sub-components. The printed circuit board plant has a supplier of electronic components.

The inter-enterprise level

At the inter-enterprise level of the HE, the notion of a mediator agent to coordinate the high-level elements of the manufacturing holarchy is used. The resulting virtual cluster of manufacturing plants, illustrated in Figure 8, consists of the following elements:

- Telephones manufacturer, consisting of an assembly plant which acquires (via the manufacturing mediator) the necessary components for building these products and assembles them.
- Cable supplier – direct supplier for the main manufacturer.
- Transmitter receiver plant.
- Printed circuit board plant. Has one supplier of electronic components.
- Power adapters plant.
- Moulded cases plant.

This level is emulated via the interactions among the plant agents shown in Figure 8. These agents emulate the roles of the manufacturers listed previously. For example, the assembly plant agent will have two main tasks, "MakeTelephone" and "MakeAnsweringMachine" and the power adapter plant will perform a task called "MakeAdapter". The manufacturing mediator agent coordinates the interaction between the plant agents and makes sure that the customer request is taken care of in due time by interacting (via the assembly mediator) with the order, logistics and transportation agents/holons acting at the next lower level as is illustrated in Figure 9.

The negotiation process is driven by the manufacturing holarchy need for a specific resource. When a resource has been produced or received it is made available to the entity in the collaborative cluster that needs it. Agents know about each other's capabilities through a directory facilitator (DF) (FIPA, 2002) embedded within the manufacturing mediator. To initiate and engage in a transaction dialogue, agents will be equipped with appropriate protocols and abilities that influence their dealings with others.

The intra-enterprise level

At the intra-enterprise level of the HE, the following entities are identified for the assembly plant holarchy illustrated in Figure 9:

- Assembly mediator (encapsulating the logistics functions) responsible for coordinating the collaborators and suppliers by interfacing with the manufacturing holarchy and negotiating the production and delivery of needed resources (components, materials) to fulfill customer requests.
- The customer – who triggers the production and transfer of resources on demand.
- The order manager – responsible for acquiring orders and handling customers' requests.
- Planning and scheduling unit that allocates the enterprise resources and interfaces with the resource level.
- The transportation unit – responsible for the management of transportation resources.
- The distribution centre – that uses the transportation resources to distribute materials and supplies to the assembly sections as needed.

The assembly plant agent/holon decomposes at the intra-enterprise level into the assembly holarchy presented in Figure 9:

- The customer agent (enabled with an interface) acts on behalf of the customer and via the order holon triggers the production and transfer of resources.
- The order holon handles requests from customers, approving orders and getting information regarding the orders.
- The assembly mediator coordinates the plants and suppliers and negotiates the production and delivery of needed resources across the collaborative holarchy to fulfill the order placed by the order holon. For this it closely interacts with the manufacturing mediator.
- The planning holon decomposes into the assembly planning holarchy presented in Figure 10, via which it allocates resources to fulfill the order in due time.
- The transport agents are responsible for the allocation and scheduling of transportation resources required by the logistics agents.

Figure 8
Phone manufacturing inter-enterprise holarchy

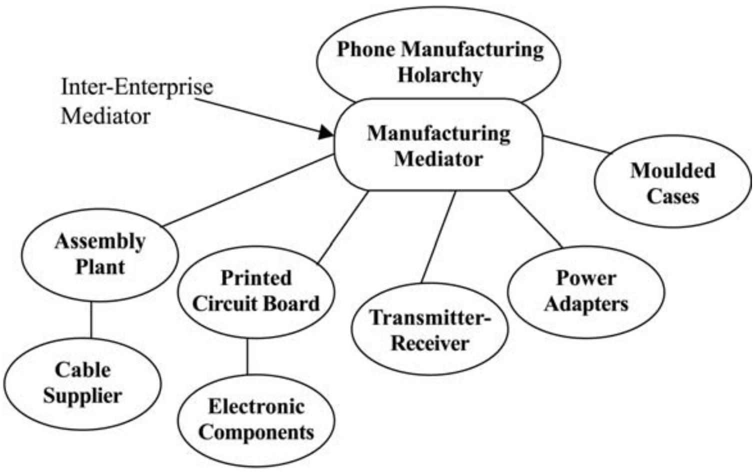
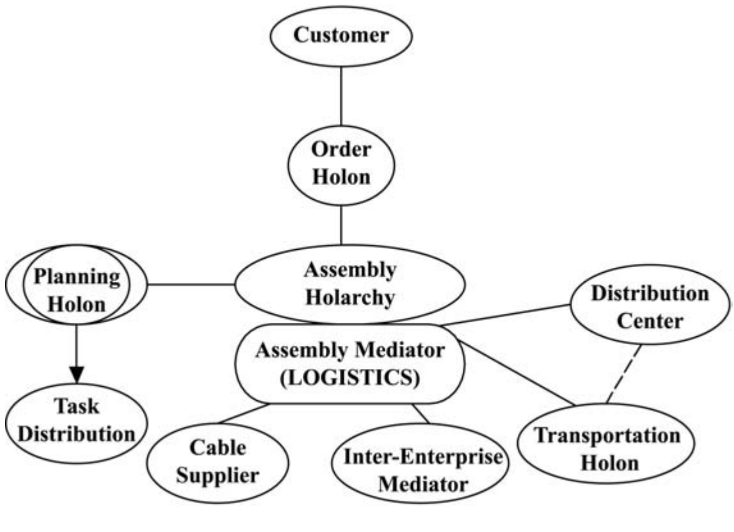


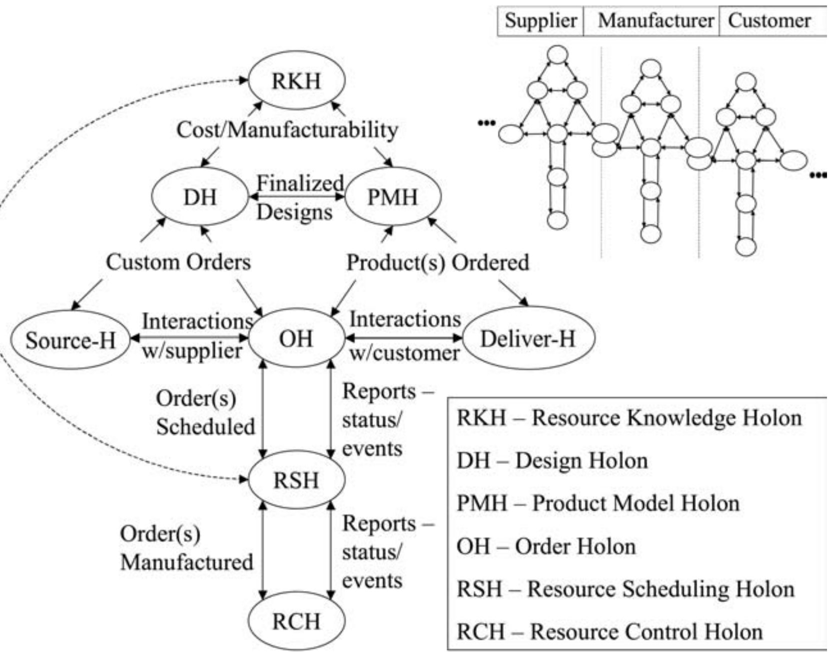
Figure 9
Phone manufacturing intra-enterprise holarchy



At this level, the collaborative partners are the sections and departments within the enterprise among which the overall task for the enterprise has to be distributed and scheduled. The assembly planning holarchy passes the received orders down to the manufacturing resources from the assembly plant. The resource knowledge holon has an inventory of all available assembly machines as well as the parts available to be assembled. The order holon passes the order received from the customer to the resource knowledge holon (RKH) via either the design holon (DH) or the product model holon (PMH) – depending on the nature of the order.

If products of that kind have been manufactured before by the assembly plant then the PMH will search for the manufacturability model and pass it on to the RKH. If this is a new product then the DH will first create a product model and then pass it to the RKH. The RKH collaborates with the resource scheduling holon (RSH) to allocate the available parts and materials to the available assembly machines in order to build the particular kind of telephones by the due date of the order. To optimize production efficiency and cost the RKH and RSH collaborate closely with the assembly

Figure 10
Assembly planning holarchy



mediator. Once the schedule is in place it is deployed on the assembly machines via the mechanism described in the next sub-section.

The machine level

Any sort of automated matching – between product orders and the resources on which they are to be processed – requires a common ground for comparison. One possibility, used frequently in manufacturing, is to use group technology to provide standardized descriptions for product features and resource capabilities (Bauer *et al.*, 1994), which can allow the determination of product families and resource work-cells/ lines and illuminate overlapping resource capabilities for flexible routing of orders. The automated decomposition of products/orders into their constituent features and processes is then possible. This is useful for automated order routing (Walker *et al.*, 2001), as well as for the concurrent design process (Xue, 1999). The dispatching, scheduling, and processing of an order on the resources of our manufacturing assembly example is done via the production holarchy presented in Figure 11.

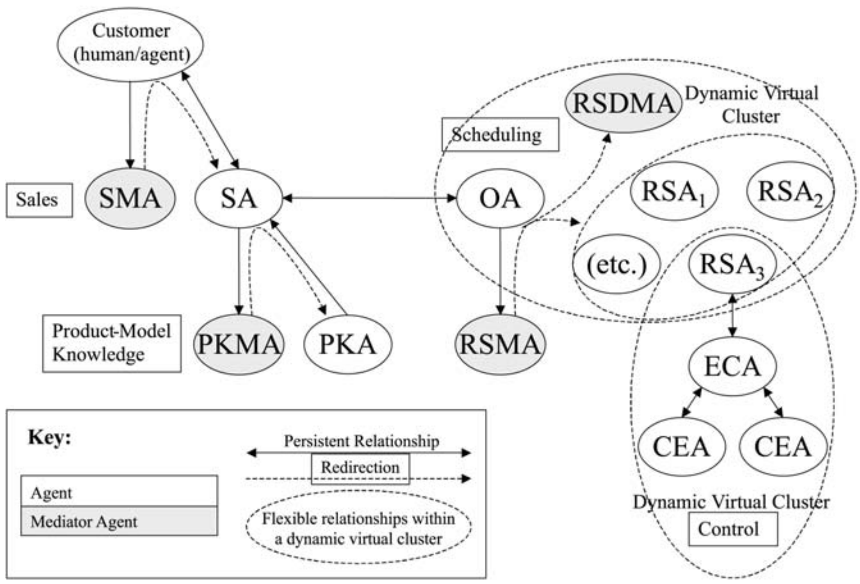
In this Figure, the order is initiated by the customer once an acceptable agreement has been reached with the sales agent (SA). In this case, the customer is directed to the appropriate SA by the sales mediator agent (SMA). The order is then managed by an order agent (OA) as is shown in Figure 11. In order to determine the appropriate resources to execute the order, the OA first consults a resource mediator agent (RSMA), then a dynamic virtual cluster of agents is formed for the duration of the order consisting of the OA and resource agents (RSA). This dynamic virtual cluster is coordinated by a resource scheduling dynamic mediator (RSDMA). Finally, as is shown in Figure 11, each resource is managed using the EC/CE/E agent structure defined in Figure 7.

At this point, we can continue our example at the machine level. The machine level example focuses on a single assembly cell in the assembly plant. As is shown in Figure 12(a), this cell consists of two robots and a conveyor. The task for this cell is to assemble "Model A" circuit boards. To accomplish this, the task is decomposed (by an EC agent) in to robot and conveyor control sub-tasks (that are managed by CE agents), and the appropriate control applications are distributed to the robot and conveyor hardware (as E agents running on the hardware).

Conclusions

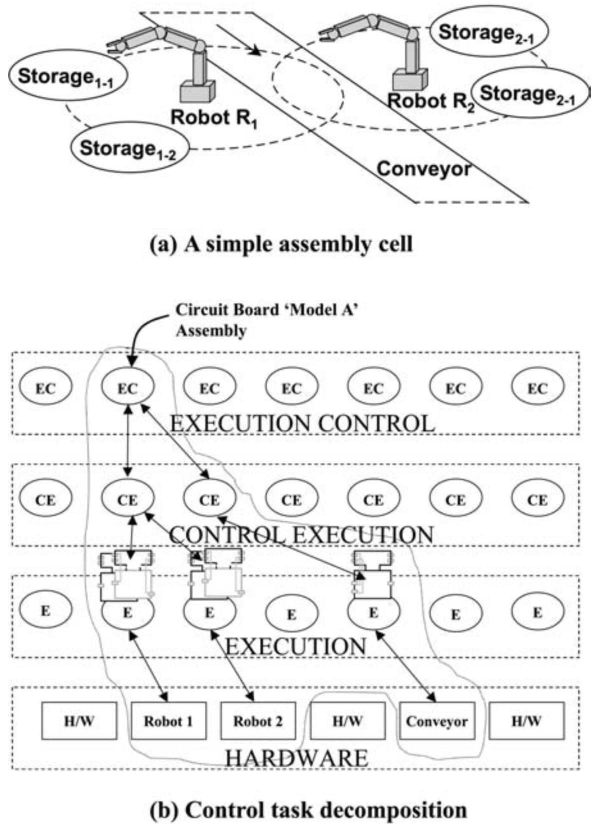
Emerging from the synergetic blend of the triad Holonics-MAS-Internet, the HE enables participants in the global market to enter strategic partnerships via the WWW while harmoniously managing the workflow throughout the resulted collaborative holarchy. At the highest inter-enterprise collaborative level, the main shift is from the closed system philosophy of the traditional

Figure 11
Production holarchy



supply chain management to the open system philosophy governing a collaborative cluster of partners devoted to the same goal. Inside each enterprise the planning and scheduling level transfers the tasks onto the available resources – the lowest level – via dynamic, reconfigurable software technologies, in a manner that also supports monitoring and fault-recovery for order processing. At the physical machine level, recent advances in distributed control system models, software and hardware are used to realize a distributed process automation system with intelligent control components.

Figure 12
Phone manufacturing machine level holarchy



There are already several tools that facilitate the implementation of our HE model. Those players that will enter the global networked economy through a gateway to the HE will definitely race with a high competitive advantage. Our current work focuses on the implementation of the HE model presented here for a multi-national corporate manufacturer. This will result in shorter up-front commissioning times as well as significantly more responsiveness to change (e.g., by utilizing the reactive properties of autonomous and cooperative agents) than current SAP and SCADA systems.

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Supply chain modelling – a co-ordination approach

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Keywords
Supply chain, Modelling, Co-ordination, Integration

Abstract
One of the typical issues in supply chain management (SCM) implementation is how to capture the complexities of supply chains. This paper reviews the existing supply chain modelling methods, and identifies the limitations of current methods. Based on these, a novel co-ordinated supply chain modelling approach is proposed to capture the complexity of supply chains from the views of scenario, interdependency, process and information. The proposed method is comprehensive, inclusive and aims to capture the complexities of a supply chain, align supply chain processes, and provide the basis for supply chain integration.

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Introduction

The significance of supply chain modelling lies in two aspects: first, in order to manage the supply chain effectively, it should be properly modelled; second, processes to be integrated and co-ordinated need to be modelled (Vernadat, 1996). Supply chain modelling is a prerequisite for supply chain integration. Businesses today seek models for the engineering, implementation and further development of IT-supported business relationships (Fleisch and Osterle, 2000). It is significant to study powerful modelling approaches to capture these complexities of supply chains and facilitate supply chain integration. In general, the main motivations for supply chain modelling are:

- capturing supply chain complexities by better understanding and uniform representation of the supply chain;
- design supply chain management (SCM) process to manage supply chain interdependencies;
- establish the vision to be shared by supply chain partners, and provide the basis for Internet-enabled supply chain co-ordination and integration;
- reduce supply chain dynamics at supply chain design phases.

Modelling is the basis for integration. Internet technology-enabled supply chain integration depends on an effective supply chain modelling approach to describe the components and elements of the supply chain. Based on enterprise modelling and co-ordination theory, a novel supply chain modelling approach is proposed in this paper to describe the supply chain from different views. The approach aims to describe the complexities of supply chains, align supply chain processes, and provide the basis for supply chain integration.

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Literature review

A number of supply chain modelling methods and management methodologies have been proposed to describe the supply chain from different aspects, such as process, structure and decision mechanism. Supply chain operations reference (SCOR) model was developed by the Supply Chain Council. It is intended to be a cross-industry standard in SCM process definition and configuration (Supply Chain Council, 1997, 2000). It views the supply chain as a chain of processes. The models are purposefully designed to be configurable by accommodating flexible combinations of hierarchical processes. SCOR is a concise reference model that mainly focuses on supply chain processes and process metrics.

Cardiff supply chain re-engineering methodology (Berry *et al.*, 1995; Towill, 1996) is proposed by Cardiff Industrial System Dynamics Group, at the University of Wales, Cardiff. It uses control theory approach to model the supply chain, and provides a structural framework, combining qualitative and quantitative tools and techniques for supply chain dynamics reduction. Nevertheless, this methodology does not effectively represent the high complexities of supply chain; for example, the organisation interdependencies.

A process handbook project conducted at Massachusetts Institute of Technology (MIT) involves collecting examples of how different organisations perform similar processes, and organising these examples in an online "process handbook" (Malone *et al.*, 1999). It is a tool for sharing and managing business process knowledge. The MIT Supply Chain Process Handbook (SCPH) is a subset of the MIT Process Handbook. In the SCPH, a process-oriented method is proposed to represent business process in supply chain.

Collaborative planning, forecasting and replenishment (CPFR) model (VICS, 1997) aims to create collaborative relationships between buyers and sellers through co-managed processes and shared information. By integrating demand and supply processes, CPFR will improve efficiencies, increase sales, reduce fixed assets, working capital, and inventory for the entire supply chain while satisfying consumer needs. The model includes guidelines for the business processes, supporting technology and organisation change associated with implementation.

In recent years, many researchers (Barbuceanu and Fox, 1995; Lin *et al.*, 1998, 1999a, b; Parunak and Vanderbok, 1998) have used multi-agent technology in supply chain modelling. In agent-based modelling, organisation units and processes are designed as agents that have their particular objectives, behaviours and interfaces. Agents exchange messages for communication purposes. Intelligent decision and learning rules are defined in agents. Supply chain performance is supposed to be improved by the co-ordination between agents. Although the application of multi-agents in SCM seems appropriate and novel, limitations still exist. The main limitation is that the current agent technologies are still in the development phase and not adaptive enough to meet the rich dynamics in supply chain reengineering and execution.

Additionally, based on the concept that modelling is the basis for integration, many research studies have been conducted on enterprise modelling since the mid-1980s. CIMOSA (AMICE, 1991, 1993; Vernadat, 1993) is proposed to help companies to manage change and integrate their facilities and operations to face world-wide competition. The basis to achieve this is an integrated enterprise model. CIMOSA offers the most comprehensive and formal enterprise model representation. It provides a consistent architectural framework for both enterprise modelling and integration. It has paved the way and proved the validity of the model-based enterprise integration approach. Other research in enterprise modelling include SADT (Ross, 1985), IDEF0, architecture of integrated information systems (ARIS) (Scheer, 1992, 1994), Purdue Enterprise Reference Architecture (PEAR) (Williams, 1992, 1994), and GRAI method (Dooumingts and Chen, 1993). Fleisch and Osterle (2000) developed an approach which links process orientation and organisation networking. The result is a model of IT-supported business relationships for a networked enterprise. Although these methods have their advantages on enterprise modelling, they mainly focus on the integration inside each individual enterprise, do not address typical problems in the supply chain, and give limited emphasis to supply chain interdependencies and the integration of the supply chain network.

In summary, because of the complexities in supply chains, the representation of inter-organisation relationships, the alignment of processes, and the synergy of supply chains are very challenging. As the patterns between partners might be different due to the diversities of products and the morphology is dynamic over time, the process of producing comprehensive or rigorous maps of the network is clearly a challenge. Further study on supply chain modelling is needed.

Supply chain modelling – a co-ordination approach

A supply chain is a complex inter-firm network with multi-participants and processes, and every participant is an autonomous or semi-autonomous participant. The organisations co-ordinate with each other to produce products for the final customers. Malone and Crowston (1994) initiate the building of co-ordination theory and give the definition of co-ordination as "... managing interdependencies between activities". Since a supply chain is a network with multiple organisations with complex interdependencies, co-ordination theory is applicable to it.

The modelling method proposed in this paper is defined as a co-ordination approach because a supply chain is co-ordination intensive and co-ordination theory is applied in modelling. First, in a supply chain network, with shrinked market margins, time-based competition, low-inventory and limited facilities capacities becoming the realities of supply chain network, the interdependencies among organisations are more and more close. Co-ordination as the process to manage interdependencies is more and more imperative. Second, during the realisation of customer-required products, interdependencies arise among supply chain organisations that complement each other in producing or commercialising the products. These interdependencies may be inherent in the structure of the problem, or they may result from decomposition of tasks, or the assignment of activities to actors and resources. Co-ordination of activities and management of supply chain relationships can be a source of competitive advantage and can bring additional value to the customer (Kalakota and Whinston, 1997). Third, business process management addresses organisational co-ordination both internally and with partners who are customers or suppliers (Armistead *et al.*, 1999). Since all the material and information flows in supply chain are realised by supply chain processes, the design of co-ordination processes is vital for successful supply chain management. Furthermore, due to the complexities of the supply chain, it is difficult to describe its overall behaviour from a single standpoint. An obvious way of reducing complexity is to segregate the totality into different dimensions. Each dimension should be structured and designed independent of the other dimensions.

The proposed co-ordinated supply chain modelling approach describes supply chain co-ordination structure, interdependency, process and information to provide the basis for Internet-based supply chain integration. A scenario model describes the total supply chain structure as a network of product and service flows. The network should be linked and integrated by Internet-based technologies and applications. The interdependency model describes the co-ordination relationships between supply chain nodes which need to be managed by the Internet technology enabled co-ordination process. The process model studies all the activities that manage the interdependencies and realize the customer-required products. The co-ordination mechanism is represented as a mathematical model which in fact is the co-ordination objective function. The search process of the feasible solution could be designed in a supply chain planning or decision-making application. The co-ordination process could be wholly or partly realized by Internet technology to be called the "e-process". The information model is generated based on the process requirement. Information supports the execution of the process and is collected and distributed across the Internet. The supply chain models give a whole picture of the components and relationships to support Internet technologies based supply chain integration.

Scenario model

A scenario is defined as "a scientific description of a speculative model intended to account for observable facts". The concept of a scenario can be used to describe the structure of a supply chain network. A scenario is also defined as "a description of an imagined situation of postulated events". Since dynamics is the instinct of supply chains, different products, organisations, interdependencies and processes may form different supply chains. For a company to maintain its competitiveness, it is necessary to image, design and evaluate different supply chain scenarios before the implementation of SCM.

Influence factors in scenario developing

Due to the dynamics in market, organisation relationships and technologies, supply chains are embedded in complex networks of influences. In order to fit into the right supply chain, an enterprise should be studied in a system of linked influences. First, customer success requires that a firm understands its customer's desire in product/service packages. Providing product/service packages that help customers succeed assures not only survival but also prosperity in today's intensely competitive economy. More and more original equipment manufacturers focus on their core business and outsource components from their suppliers. Second, organisations have to co-operate with each other in meeting the ever-changing customer demands. Fitness is the extent to which the goals of a subsystem are compatible with those of others in an overall system. Achieving an effective fitness in a supply chain is concerned with configuring supply chain structure and organisation relationships that enable individual firms to organise and utilise its resources efficiently while contributing to the effective functioning of the whole supply chain. Third, the application of different production strategies may cause different supply chain structures that are with different performance effects. The production strategies may include make-to-order (MTO), make-to-stock (MTS), postponement, outsourcing, etc. Fourth, system dynamics is an intrinsic characteristic of a supply chain. Wikner *et al.* (1991) stated that supply chain dynamics would be increased with the increase in supply chain echelons. The determination of the number of supply chain echelons is also important in supply chain scenario development. Finally, organisation location is also an important influencing factor on a supply chain. Long distance between supply chain nodes normally means long delivery lead-time, more uncertainty in information and material flows and higher distribution costs. The locations of nodes may affect the structure and the behaviour of a supply chain. For a company, in order to fit into the right supply chain, the above factors should be considered in scenario developing.

Scenario modelling

The scenario model can be defined as co-ordination network model that is composed of supply chain nodes and links. A supply chain node is defined as an organisation entity that is located at a particular location and processes a particular product. It can be a plant, a warehouse, a supplier, or a distributor. A node is distinguished by product/service, location and organisation related attributes as displayed in Figure 1.

- *Product/service*: refers to the material produced and the service provided by supply chain organisations.
- *Organisation*: refers to the supply chain entities that produce customer-required products/services. An organisation has many attributes in function, capacity, resources, and production strategy.
- *Location*: is the place where supply chain activities are conducted.

An organisation may exist in more than one location, and at a particular location there may be multiple organisations. An organisation can produce one or more types of product. However, specific product, organisation and location define a particular supply chain node. Supply chain nodes can be divided into three basic types:

1 product manager;
2 processor; and
3 function broker.

A product manager is a node that is responsible for the accomplishment of a customer-required product. It assigns a product-related task to other supply chain nodes. A processor is a supply chain node that receives tasks from others and produces the products for other organisations to fulfil a customer requirement. A function broker node is the information broker that manages processor nodes of the same type. It receives tasks from the product manager and assigns the tasks to processors. The function broker does not conduct direct execution activities such as manufacturing and distribution.

Figure 2 shows a graphic representation of a supply chain scenario. An uppercase M is added before the node name to represent a product manager node. An uppercase P is added to represent a processor node, and an uppercase B is added to represent a function broker node. The node M_P0_L0 is a product manager node, which outsources components pm1 and pm2 from manager node Ms1 and function broker B1 and produces product p0. B1 manages three processors Ps1, Ps2 and Ps3 to produce component pm2. The distributor MD1 and MD2 are also manager nodes that get product p0 from M or other manufacturers.

A link is the linkage between two supply chain nodes based on their relationships over time. It constitutes recognition of interdependence. A link can be specified by attributes such as link-ID, name, organisation, and relationship type, etc. A link defines the material supply and co-ordination structure between two supply chain nodes. The co-ordination structure is a pattern of decision making and communication among nodes that perform supply chain tasks. According to the difference in task assignment, three types of basic supply chain co-ordination structures are defined. They are product hierarchy, decentralised market and functional brokering.

In the product hierarchy structure, the product manager assigns a task to a particular processor or other product manager node, and for a particular task, only one processor is assigned. For example, a manufacturer assigns an order to its subcontractor. In a decentralised market structure, the product manager auctions a task to multiple processors that are of identical specialisation, receives bids from them, and then assigns the task to whoever provides the best bid. In a functional broker structure, the product manager does not communicate directly with processors, it assigns a task to a functional broker, who manages a set of processors with identical specialisation. In graphic representation, a link is specified by a super character beside the link line as shown in Figure 2. "P" represents product hierarchy, "D" represents decentralised market, and "B" represents functional broker structure.

Scenarios are the result of the scenario development process. For a company, multiple supply chain scenarios can be developed with the difference in products, co-ordination structures and production strategies.

Figure 1
Attributes of a supply chain node

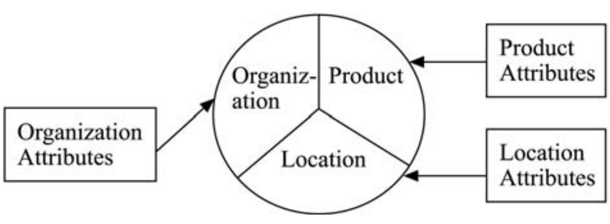
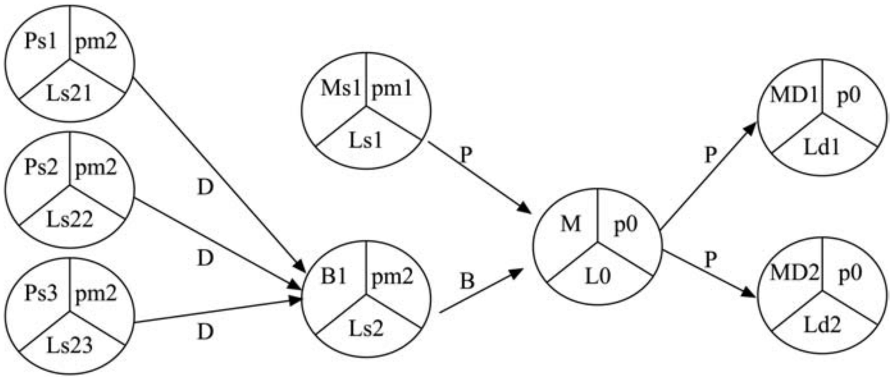


Figure 2
A graphic representation of a supply chain scenario



Interdependency model

Inside a supply chain scenario, organisations enter into a complex set of interdependencies with other firms. Given that the co-ordination structure is defined in a supply chain scenario, the interdependency modelling method proposed here will deal with how to identify, classify and represent interdependencies in a supply chain.

Litwak and Hylton (1962) define interdependency as when two or more organisations must take each other into account if they are to accomplish their goals. McCann and Ferry (1979) defines interdependency as "when actions taken by one referent system affect the actions or outcomes of another referent system". From these definitions, several characteristics of supply chain interdependency can be seen. First, interdependency is the reality in supply chains. In order to fulfil the customer requirement, interdependencies always exist in a supply chain. Second, interdependency involves the outcomes of the activities. Third, the more specific the interdependency is identified, the deeper the level would be at which co-ordination strategy can be executed.

The main dimension of the interdependency typology involves the types of objects involved in the dependency (Malone and Crowston, 1994). Since the major concerns in a supply chain are customer-related tasks and the resources used to accomplish the tasks, to simplify the typology, the types of objects are compressed into two groups: tasks and resources. Tasks refer to what has to be done or to be realised, such as customer order, production order, etc. Resources refer to what is being used or created by the activities to realise tasks, such as organisation, capacity, inventory, backlog and money. Logically, there are three types of interdependencies between tasks and resources: those between tasks, those between resources and those between a task and a resource.

The concept of a supply chain network is used in identifying supply chain interdependencies. There are multiple layers of organisations in a supply chain network and there may be multiple organisations at each layer of the network. Figure 3 shows a generic supply chain structure, which will be used in the interdependency analysis.

Task/task interdependency

Task/task interdependency refers to the interdependency of tasks between and internal supply chain organisations, such as order prerequisite interdependency or demand interdependency.

Order prerequisite interdependency

Customer orders are typical tasks, which are assigned between supply chain nodes. As displayed in Figure 3, if make-to-order strategy is employed in the focal firm O_i, order-prerequisite interdependency exists between the order assigned to a supplier and the orders assigned to O_i by customers. Prerequisite interdependency represents the relationship between the order rate from the customer and the order rate to the supplier. In order to fulfil the customer order, the sum of the input materials plus initial inventory should be more than the total demand of customers at any time. Also, the customer order should be fulfilled during the order lead-time, the sum of purchasing order lead-time and local processing lead-time should be less than the customer order lead-time. So the order prerequisite interdependency can be represented as:

$$\int_{t0-LT_i+1}^{t-LT_{i+1}} Orate_{i+1}(t)^* dt + INV_i(t0) \geq \int_{t0}^{t} Orate_i(t)^* dt \qquad (1)$$

$$LT_i + 1 \leq LT_i \quad (2)$$

where

$Orate_i(t)$ Order rate to supply chain node O_i.
LT_i Lead-time of the order to node O_i.
$INV_i(t)$ Inventory at time t in node O_i.

Demand interdependency

Dynamics caused by poor demand interdependency management is one of the most contributing factors to supply chain dynamics. When an organisation in a supply chain employs the production strategy of make-to-stock, demand forecasts are used to drive the production activities. Based on the demand forecast, purchasing orders will be produced and assigned to the suppliers. Additionally, the suppliers also produce demand forecast to predict demand trend.

In the generic structure as shown in Figure 3, the forecasts produced in supplier O_{i+1} and that in the company O_i are closely related. In order to fulfil the customer orders in a generic supply chain, at any time, the demand forecast in the supplier O_{i+1} with an order lead time plus the inventory in O_i should be more than the demand forecast in O_i. For a company O_i, the demand interdependency can be represented as:

$$\int_{t0-LT_{i+1}}^{t-LT_{i+1}} Demand_{i+1}(t)^* dt + INV_i(t0) \geq \int_{t0}^{t} Demand_i(t)^* dt \quad (3)$$

where $Demand_i(t)$ is the forecast value of demand rate in node O_i.

Task/resource interdependency

Task/resource interdependency refers to resource requirement in realising a task in a supply chain. It highlights the organisations, capacities and material that should be assigned to a particular task. Three task/resource interdependencies: order/organisation, order/inventory, and order/capacity interdependency are identified.

Order/organisation interdependency

Order/organisation interdependency is the interdependency of the organisation requirement in accomplishing a particular task. The process to manage order/organisation interdependency aims to build the task allocation model which matches the orders with supply chain nodes according to organisation specification and co-ordination structure.

Order/inventory interdependency

Order/inventory interdependency is the interdependency between orders and material availability in a supply chain. The materials include local finished product, scheduled materials included in master production schedules, and raw material that are available in suppliers. In order to fulfil a customer order within order lead-time, the volume of available material should be more than the order quantity at any time. The order/inventory interdependency in a supply chain node can be generically represented as:

$$\int_{t0-LD_{i+1}}^{t-LD_{i+1}} Drate_{i+1}(t)^* dt + INV_i(t0) \geq \int_{t0}^{t} Orate_i(t)^* dt \quad (4)$$

where:

$Drate_i(t)$ is delivery rate in node O_i.
LD_i is delivery lead-time in O_i.

Order/capacity interdependency

Only managing material availability is not sufficient, raw materials need manufacturing processes to transfer them to products, and finished goods need distribution processes to deliver them to the right place. Order/capacity interdependency is the dependency between a task to an organisation and the organisation capacity of manufacturing and/or distribution. Only if the capacity of the organisation matches the task's capacity requirement, the task should be assigned to this organisation. For a particular supply chain node, in order to meet customer requirement, production and distribution rates should match product demand rate. The order/capacity interdependency can be generically represented as follows:

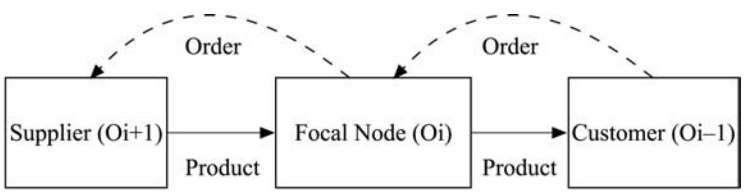
$$\int_{t0-LT_i}^{t-LT_i} CAP_i(t)^* dt + INV_i(t0) \geq \int_{t0}^{t} Orate_i{}^* dt \quad (5)$$

where, $CAP_i(t)$ is the capacity rate in node O_i.

Resource/resource interdependency

Resource/resource interdependency is the interdependency between resources such as capacity and inventory in supply chain. The

Figure 3
A generic structure of a supply chain



resource/resource interdependencies can be divided into three types:

1 supply interdependency;
2 inventory interdependency; and
3 capacity interdependency.

Supply interdependency

Supply interdependency occurs between multiple material suppliers. There are two types of supply interdependencies:

1 identical supply interdependency; and
2 compliment supply interdependency.

Identical supply interdependency is observed in the situation where two or more suppliers combine to fulfil orders from the same customer. The supplier nodes provide the same type of product, and compete against each other to win the task from a customer.

> *'... The basic constraint to capacity interdependency is that the total capacity in all supply levels should match the order requirement of final customers.... '*

The requirement for identical supply interdependency is that the total products received from all suppliers should match the customer demand during a given period. As in Figure 3, the identical supply interdependency can be represented as:

$$\sum_{j_{i+1}=1}^{m_{i+1}} \int_{t0-LD_{i+1j_{i+1}}}^{t-LD_{i+1j_{i+1}}} Drate\ _{i+1j_{i+1}}(t)^{*}dt + INV_i(t0) \geq \int_{t0}^{t} Orate_{i-1j_{i-1}}(t)^{*}dt \quad (6)$$

where:

k	Type of material from i +1 level suppliers, $k = 1, l$.
$Drate_{i+1j_{i+1}}(t)$	Product input rate from supplier node $O_{i+1j_{i+1}}$.
$Orate_{ij_i}(t)$	Order rate to O_{ij_i} from customer node $O_{i-1j_{i-1}}$.
j_{i+1}	The number of supplier nodes in $i+1$ level.
j_{i-1}	The number of customer nodes in $i-1$ level.

Compliment supply interdependency is observed in the situation where two or more suppliers provide different components to a product manager node that assembles these components to produce final products. In order to match supply and demand in the supply chain, during a period of time, the delivery rates of all suppliers and also the procurement rate of customers should match each other. In an organisation O_i in a supply chain network, the compliment supply interdependency can be represented as:

$$\begin{aligned} &\sum_{j_{i+1}=1}^{m_{i+1}} \int_{t0-LD_{i+1j_{I+1}}}^{t-LD_{i+1j_{J=1}}} Drate^{1}_{i+1,j_{i+1}}(t)^{*}dt + INV^{1}_{i}(t0) = \ldots = \sum_{j_{i+1}=1}^{m_{i+1}} \int_{t0_{LD_{i+1,j_{i+1}}}}^{t-LD_{i+1j_{i+1}}} \\ &(Drate^{k}_{i+1,j_{i+1}}(t)^{*}dt + INV^{k}_{i}(t0) \\ &= \ldots = \sum_{j_{i+1}=1}^{m_{i+1}} \int_{t0-LD_{i+1,j_{i+1}}}^{t-LD_{I+1J_{I+1}}} Drate^{l}_{i+1,j_{i+1}}(t)^{*}dt \\ &+ INV^{l}_{i}(t0) = \int_{t0}^{t} Orate_{i,j_t}(t)^{*}dt. \end{aligned} \quad (7)$$

Inventory interdependency

Inventory is kept for expected customer demand. The inventory at a supply chain node is interdependent with the inventories of its suppliers and the consuming rate of customers. The inventory data at all supply chain nodes should be collected and aggregated, and the interdependencies of inventories should be managed. In a generic supply chain in Figure 3, the delivery rate in organisation O_{i+1} is also the supply rate to the customer node of O_i with an order lead-time. When considering the material supply, the inventory in organisation O_i can be represented as:

$$INV_i(t) = \int_{t0-LD_{i+1}}^{t-LD_{i+1}} Drate_{i+1}(t)^{*}dt + INV_i(t0) - \int_{t0}^{t} Drate_i(t)^{*}dt.$$

Similarly, the inventory in the supplier O_{i+1} can be represented as:

$$INV_{i+1}(t) = \int_{t0-LD_{i+2}}^{t-LD_{i+2}} Drate_{i+2}(t)^{*}dt + INV_{i+1}(t0) - \int_{t0}^{t} Drate_{i+1}(t)^{*}dt.$$

Based on these, the interdependency between the inventories of O_{i+1} and O_i can be represented as.

$$\begin{aligned} INV_{i+1}(t) &= \int_{t0-LD_{i+2}}^{t-LD_{i=2}} Drate_{i+2}(t)^{*}dt \\ &+ INV_{i+1}(t0) - (INV_i(t + LD_{i+1}) \\ &- INV_i(t0) + \int_{t0+LD_{i+1}}^{t+LD_{i+1}} Drate_i(t)^{*}dt). \end{aligned} \quad (8)$$

Capacity/capacity interdependency

Capacity interdependency exists in two supply chain nodes with close relationships where the change of capacity in one supply chain node may affect the performance of another supply chain node. The basic constraint to capacity interdependency is that the total capacity in all supply levels should match the order requirement of final customers.

The capacity interdependency exists in two situations: identical supply and complement supply. In identical supply, multiple suppliers provide the same type of material to the focal company in the i level, the total capacity of the i +1 level suppliers should match the capacity in the i level.

$$\sum_{j_{i+1}=1}^{m_{i+1}} \int_{t0}^{t} CAP_{i+1 j_{i+1}}(t)^{*}dt = \int_{t0}^{t} CAP_{i}(t)^{*}dt = \int_{t0}^{t} Orate_{i}(t)^{*}d \quad (9)$$

where, CAP_{i,j_i}(t) is the capacity rate at O_{i,j_i}.

In complement supply, multiple suppliers provide different materials to the focal company. Ideally, during a relatively long period, the capacities of these suppliers in i +1 level should match the capacity rate in i level organisations. This interdependency can be represented as:

$$\int_{t0}^{t} CAP^{1}_{i+1 j_{i+1}}(t)^{*}dt = \int_{t0}^{t} CAP^{k}_{i+1 j_{i+1}}(t)^{*}dt = \ldots = \int_{t0}^{t} CAP^{l}_{i+1 j_{i+1}}(t)^{*}dt = \int_{t0}^{t} CAP_{i}(t)^{*}dt = \int_{t0}^{t} Orate_{i}(t)^{*}d. \quad (10)$$

Process model

A supply chain is a chain of business processes that are involved through upstream and downstream linkages, produce value in the form of products and services to the ultimate consumers (Supply Chain Council, 2000). The real results of SCM come from the integration of processes throughout the entire supply chain from the supplier's supplier to the customer's customers. The purpose of supply chain process modelling is to design processes to manage supply chain interdependencies, and define the functionality and behaviour of SCM processes to the level of detail required by the business users. Considering process mapping and co-ordination theory, a novel process modelling method is proposed in this paper to describe process from three aspects: functionality, process flow and co-ordination mechanism.

Co-ordination and process design

According to the co-ordination theory, the activities in an organisation can be separated into those that are necessary to achieve the goal of the process (e.g. that directly contribute to the output of the organisation) and those that serve primarily to manage various dependencies between activities and resources (Crowston, 1997). In this paper, the processes in a supply chain are divided into two main classes, the co-ordination processes that manage interdependencies and the execution processes that realise the goal of organisation.

When processes are systematically compared, patterns emerge, and a similar range of possibilities will be seen. Individuals (or firms) may be either generalists who perform a wide variety of tasks, or specialists who perform only a few. Organisations that perform the same task often perform essentially the same basic activities; for example, the basic inventory management activities in manufacturing firms. A process can be a generic process used as a reference to define a particular process that is related to a particular industry. A particular co-ordination process can be designed based on a generic co-ordination process. While the general activities are the same, the processes differ in important details: how product related tasks are decomposed, who performs particular activities, and how they are assigned.

Organisations face co-ordination problems that arise from dependencies that constrain how tasks will be performed. To overcome the co-ordination problems, actors must perform additional activities, which are composed of what Malone and Crowston (1994) called co-ordination mechanisms. An important claim of co-ordination theory is that interdependencies and the mechanisms to manage them are general; that is, a particular dependency and a mechanism to manage it will be found in a variety of organisation settings. Co-ordination theory thus suggests identifying and studying common dependencies and their related co-ordination mechanisms across a wide variety of organisations. The second claim is that there are often more than one co-ordination mechanism that could be used to manage an interdependency. Organisations with similar activities to achieve similar goals will have to manage the same dependencies, but may choose different co-ordination mechanisms, thus resulting into different processes. Furthermore, the previous two claims taken together imply that given an organisation performing some task, one way to generate alternative processes is to first identify the interdependencies and co-ordination problems faced by the organisation.

Proposed process modelling method

Process modelling methods have been studied by many researches; for example, SADT (Ross, 1985), CIM/OSA (AMICE, 1993; Vernadat, 1992), ARIS (Scheer, 1992, 1994). Most of them are process mapping methods. This paper proposes a new modelling method to describe process from three aspects:
1 functionality;
2 process flow; and
3 co-ordination mechanism.

Functionality of process – process as a whole

A supply chain process is a series of logically related activities that combine to accomplish specific business objectives by transforming given inputs to desired outputs. The functionality of process specifies the inputs and outputs of a process. It considers the process as a whole and deals with the interface of a process to its environment. The functionality actually defines the "what to do" of a process.

Process flow

Within a supply chain process, the input is transferred to output by the process according to process logic. The execution sequence and conditions of sub-process and activities form the process flow. The process flow describes process behaviour. It shows, in a supply chain, how sub-processes and activities execute according to enterprise events and logic.

Co-ordination mechanism

The co-ordination processes are responsible for managing external and internal interdependencies, and controlling the execution processes. The co-ordination mechanism is employed in the co-ordination process to represent the co-ordination objective of managing interdependencies.

Depending on the interdependencies to be managed, the co-ordination mechanisms are different. For example, the mechanism to manage demand interdependency in a demand planning process aims to fulfil customer demand and reduce supply chain inventory and backlog at the same time. The ideal situation is that at anytime, demand forecast in O_i plus the initial inventory is equal to the demand forecast in supplier O_{i+1}. Based on equation (3), the mechanism managing demand interdependency can be represented as:

$$Min(\int_{t0-LT_{i+1}}^{t-LT_{i+1}} Demand_{i+1}(t)^* dt - \int_{t0}^{t} Demand_i(t)^* dt + INV(t0)).$$

The co-ordination mechanism to manage order/inventory interdependency can be applied in such SCM processes as available-to-promise. It minimises the difference between order requirement and inventory availability, and matches the available inventory and order size. Based on equation (4), it can be represented as:

$$Min(\int_{t0-LD_{i+1}}^{t-LD_{i+1}} Drate_{i+1}(t)^* dt + INV_i(t0) - \int_{t0}^{t} Orate_i(t)^* dt).$$

Generally, the objective of the supply chain co-ordination mechanism is to match supply and demand in demand, inventory, resource capacity and lead time.

Topology of interdependency and co-ordination process

Internet technologies enabled SCM processes are designed to collect real-time information and make fast and accurate supply chain decisions. Different supply chain co-ordination processes manage different types of interdependencies. Typical features of supply chain co-ordination processes include demand planning (DP), supply planning (SP), available-to-promise/capacity-to-promise (ATP/CTP), manufacturing planning, distribution planning (DP), etc. A topology of interdependencies and related co-ordination processes is given in Table I.

The analysis of the specific process is at least as important as the general issues. In analysing alternative processes for specific problems, various kinds of properties of processes can be considered: the production costs, co-ordination costs, the speed of the process, the stability in the face of failures of actors, etc. These kinds of issues need specific consideration in process design.

Information model

The execution of process depends on proper information management. Internet technology enabled information integration within and between organisations is critical to SCM. The objective of information modelling is to identify process information requirements and establish information conceptual schema that provide a clear description of the information entities relation. The information model and process model are inter-dependent. First, the input/output information of a process are the entities that can be represented by information objects. The accomplishment of a process must depend on the entities that represent information and material that flow through the process and support the process.

Second, the information model will be built around a process objective. Corresponding to a specific process, there will be a related information schema that expresses the relationship of entities, which is related to realisation of the process.

A number of modelling methods in entity-relation modelling and objected-oriented modelling exist that can be chosen for supply chain information modelling purpose, such as the ER method by Chen (1976, 1981), and object-oriented analysis methodologies by Coad and Yourdon (1990) and Booch (1994). The most important point to note is that the final outcome is the key consideration, not the choice of one analysis technique over another technique (Burleson, 1998).

Conclusions

In this paper, a co-ordinated supply chain modelling approach is proposed to describe the complexities of supply chains from the views of scenario, interdependency, process and information. The approach aims to capture the complexities of a supply chain, align supply chain processes, and provide the basis for Internet-enabled supply chain integration. The four models are closely related, but describe different aspects of a supply chain to provide the basis for Internet-based supply chain integration. It is important to understand that these four models are located on different levels of supply chain modelling. The scenario model describes the total supply chain structure as a network of product and service flows. The network should be linked and integrated by Internet-based technologies and applications. The interdependency model describes the co-ordination relationships between supply chain nodes. The process model studies all the activities that manage the interdependencies and realise the customer-required products. The co-ordination process could be wholly or partly enabled by Internet technologies to be called the "e-process". The information model is generated based on the process requirement. Information supports the execution of process, and is collected and distributed across the Internet.

The proposed approach may benefit the users from several aspects. First, it helps the user to capture supply chain complexities by better understanding and uniform representation of supply chain elements, and presents a clear view of a supply chain. Second, the identification of supply chain interdependency helps to invent and design SCM co-ordination process. Third, the approach can be used to establish the vision to be shared by supply chain partners, and provide the basis for Internet-enabled supply chain co-ordination, integration, and reinvention. Furthermore, based on the established model, the performance of a supply chain can be evaluated to reduce dynamics, identify the constraints and detect the feasibility of SCM implementation. Therefore, the approach can be an innovative decision support tool in supply chain continuous improvement.

Table I
The topology of interdependency and process

Interdependency type	Interdependency	Coordination process
1. Task/task interdependency	Demand interdependency	Demand planning
	Order prerequisite interdependency	Manufacturing planning
	Order resource sharing interdependency	Manufacturing planning
2. Task/resource interdependency	Task/capacity interdependency	Capacity-to-promise
	Task/organization interdependency	Manufacturing planning
	Task/inventory interdependency	Available-to-promise
3. Resource/resource interdependency	Supply interdependency	Transportation planning
	Inventory interdependency	Supply planning
	Capacity/capacity interdependency	Collaborative capacity planning

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Enterprise integration: creating competitive capabilities

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Keywords
Integration, Internet, Supply-chain management

Abstract
For manufacturing firms, the concept of integration is hardly novel. The Total Quality, JIT, and supply chain management movements required improved internal and external coordination. While these movements centred on the manufacturing function, research suggests that integration of several functions at different organisational levels achieve above average financial and performance results. However, studies show enterprise integration is associated with many problems; at the root of these is a fundamental assumption: that all enterprise integration initiatives are equally important. Challenges this assumption. Argues that enterprise initiatives differ by their purpose; and proposes a framework for typifying enterprise integration initiatives that is based on the capabilities developed for the organisation. Four types of enterprise initiatives are identified. Illustrates each type with organisational examples. Discusses the managerial implications.

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Introduction: contemporary demands for Enterprise Integration

All organisations face the strategic challenge of achieving sustained profitable growth. To meet this challenge, organisations develop capabilities that enable them to compete in their market space (Barney, 1991). When set against an organisation's structure chart, these capabilities rarely fit neatly into the functional silos. Senior managers are learning that the exploitation of capabilities requires high levels of integration across the enterprise's functions. Although much has been written by academics and practitioners on enterprise integration, the actual integration of functions in practice is less frequent and less deep than one might expect, having read the literature. A closer examination of projects that can lead to capabilities, such as Internet Technologies, Enterprise Resource Planning (ERP) systems, mass customisation and supply chain management, reinforce the imperative to integrate across functions.

Organisations that want to exploit Internet technology opportunities are advised to develop strategies to progress beyond brochure-ware and electronic catalogues and offer complete services such as order fulfilment (Baker, 1999; Venkatraman, 2000). Organisations require several functions such as sales, production, and finance to work together seamlessly to complete such transactions; however, peoples' willingness to knit their activities is altogether uncertain (Braganza and Morgan, 2000). In the pre-Internet, electronic data interchange, era, sales people and account managers chased customers' orders around the organisation, overcoming functional obstacles and discrete systems. Overlaying a Web interface on a dysfunctional organisation makes internal anomalies visible and transparent to customers, suppliers and shareholders.

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Unified Web-based services challenge the silo structure and prevailing power bases, as it becomes near impossible for people in the recesses of a large function to manipulate prices, delivery dates and discounts (El Sawy and Bowles, 1997). Hence, Internet technologies require organisations to integrate across silos.

Many organisations have invested significant sums of money into ERP systems. These are off-the-shelf packages that can be configured to match the needs of organisations (Markus *et al.*, 2000). At the heart of ERP packages is a database that enables organisations to structure data so that these can be shared across several applications. The database and its accompanying modelling and mining tools provide the opportunity for information to flow through the organisation (Oliver, 1999). However, recent evidence suggests that, whereas ERP has provided some benefits in terms of software standardisation, the substantive benefits of information integration have barely been realised (Kumar and Van Hillegersberg, 2000). This has led to organisations stopping ERP projects because there are too few benefits gained for the management time and financial costs invested. The ramifications of ERP are significant changes to the traditional functional structure. Hence the difficulties associated with implementing ERP can become unmanageable (Van Everdingen *et al.*, 2000). There is widespread agreement that for ERP implementation to succeed, organisations need to be integrated (Willcocks and Sykes, 2000).

For many organisations, the strategic aim of mass customisation has the potential for competitive advantage (Kotha, 1995). Mass customisation describes an organisation's ability to develop and supply products and services that are tailored to each customer's needs (Da Silveira *et al.*, 2001). It requires organisations to be flexible, quick and responsive. They need to be able to configure and re-configure people and systems in different functional departments. Therefore, organisations that pursue a mass customisation strategy need to have in place effective integration across departments in different functions (Pine *et al.,* 1993).

Supply chain management is another challenge facing organisations, especially those in the manufacturing sector. It requires organisations to optimise their operations across interfaces with stakeholders, e.g. customers, suppliers, and regulators. Supply chain improvements require organisations to collaborate, share knowledge and work towards shared goals based on recognition of mutual interdependence (Narasimhan and Das, 2002). However, as with any chain, it is only as strong as the weakest link. This link may not be at the conjoint of two organisations and may, in fact, exist at the interface of two functions within one of the supply chain partners. This is exemplified by the marketing director in one manufacturing organisation who wanted to develop joint business plans, which included sales and production figures, with key customers. His idea was to create a strong sense of partnership with these customers. An integral part of the joint business plan was the sourcing of raw materials to prepare production figures. The manufacturing director decided that raw material information was too sensitive to divulge to customers. Although the board, including the managing director, did not share this view, the manufacturing director's view prevailed. The moves to share forecast information and collaborate with customers and suppliers were stymied because the manufacturing director did not want the purchasing and sales functions to be integrated more closely. Hence, the challenge of supply chain management requires enterprise integration.

Each of the above suggests that enterprise integration remains critical to organisational prosperity. Yet past experience and research suggests that a headlong rush into cross-functional integration initiatives is unlikely to succeed. Nor is forming cross-functional or project teams an answer. These teams have seldom thrived in functionally structured organisations.

Charting previous attempts at enterprise integration

The structures of contemporary organisations can be traced back to some of the earliest armies: functional specialists embedded within a defined hierarchy. Almost 100 years ago, at the start of the Industrial Revolution, Taylor codified the rules for structuring organisations so that they could cope with the demands of that revolution. A wide range of theories were developed for managing organisations and people through the study of organisations such as General Motors, Standard Oil of Jersey and Du Pont. These theories remained within the confines of Taylor's principles (Taylor, 1911). However, a recurrent theme in the literature is organisations managed through a structure with strong functional walls are slower to adapt to fast changing environments (Bartlett, 1995). Consequently, there have been several attempts at traversing the functional silos.

Lawrence and Lorsch (1967) suggested that the role people adopted influenced the balance between functional and cross-functional dimensions. They argued that, as organisations become more complex, people specialise in a particular function. People fulfilling a specialist role become experts in carrying out a particular task, as exemplified by a tax accountant in a finance function or a researcher in a consumer marketing function. Their study showed that people in functional units pursued their objectives often to the exclusion or detriment of other function's goals. Lawrence and Lorsch (1967) argued that to achieve a higher level of collaboration between specialists in different functions, people in an integrator role acted as a bridge between the functions. In this role they resolved inter-departmental conflicts, mediated information, and ensured smooth operations across the functions (Lawrence and Lorsch, 1967). Integrators occupied general management or head office positions with job titles like: group managers, regional managers, divisional managers and geographic sector managers. During the third quarter of the last century while organisations grew by expanding their product and geographic range, so did the number of people in integrator roles. In many organisations, the numbers of people in general management or integrator roles grew disproportionately to the number of people in specialist roles (Bartlett, 1995). Head offices became bloated; fulfilling an integrator role became an end in itself. They formed a wedge between specialists in the factories, sales offices and distribution warehouses and senior managers on the board. Information as it passed from specialists, through the hands of head office general managers, to the board was changed, filtered, or withheld. People had several reporting lines and consequently decision making became slow and bureaucratic. In time, boards questioned the value of integrator roles and the numbers of people in head offices shrunk. Nonetheless, academics and practitioners recognised the need for cross-functional integration.

Through the 1970s and early 1980s, a further attempt at cross-functional co-ordination came in the form of matrix management. This involved creating a structure that could be overlaid on the existing functional silos (Burns, 1989). Matrix management structures developed liaison roles, similar to that of integrator roles, with the aim of co-ordinating across departments, so that organisations could deal with diverse and complex markets, products and services, customers, and channels to market (Galbraith, 1972; Thompson, 1967). To give the liaison role a modicum of authority, organisations appointed matrix directors, established matrix departments and developed a horizontal hierarchical structure that rivalled the prevailing vertical-functional hierarchy. The rationale for adopting a matrix structure was to create a hybrid organisation underpinned with function-by-project principles, in which authority and power shifted from being solely in the hands of functional directors to these directors and matrix directors. These principles promoted cross-functional co-ordination, participation in decisions and knowledge sharing. The matrix management concept appeared to be a simple solution when drawn on a structure chart (Burns and Wholey, 1993).

However, in practice, senior managers found themselves faced with complex and unmanageable organisational structures. Matrix organisations required people to have at least dual, and often multiple, reporting lines that led to internal conflicts. Instead of facilitating the free-flow of information, people hoarded their knowledge. Committees took decisions and the number of committees mushroomed in many organisations. People had unclear and overlapping responsibilities and accountabilities resulting in interdepartmental warfare for control of, and power over, resources. The significant inherent drawbacks to matrix management led to it being discredited as an effective mechanism for cross-functional integration (Bartlett and Ghoshal, 1990; Burns and Wholey, 1993).

The late 1980s and early 1990s saw the emergence of the re- engineering movement (Hammer, 1990). Academics and practitioners recognised that traditional functional structures fragmented people's day-to-day jobs to such an extent that they chased functional goals and optimised their departmental activities rather than pursue organisational goals and optimise business processes. Senior managers were being advised to integrate activities across silos even if that meant taking radical measures such as dismantling the functional structures (Hammer and Champy, 1993). The radical re-engineering movement developed at a phenomenal rate with academics, consultants and practitioners developing various "how to" methods (Kettinger *et al.*, 1995). Radical re-engineering became associated with information technology initiatives (Davenport, 1993). Radical re-engineering took on negative overtones as it became almost synonymous with sacking large numbers of people (Willmott, 1994). Many senior management teams entered into radical initiatives unprepared for the significant changes that would be required in the organisation (Stoddard *et al.*, 1996). Therefore, initiatives failed to be fully implemented and re-engineering, which set out to integrate functions, has become discredited (Buchanan, 1997).

Attributes of enterprise integration: current perspectives

Three key attributes emerge from the subset of the literature that focuses on enterprise integration. The first is the characteristics that define enterprise integration. The second is the scope of enterprise integration. The third theme is the range of organisational elements that would need to be co-ordinated, and hence changed in some way, as an integral part of an organisation's integration plans. Each attribute is examined below.

Attribute 1: characteristics

Enterprise integration is linkages between parts of an organisation (Fuchs *et al.*, 2000). The parts that are to be aligned include strategic direction, market focus, resources, skills and culture (Porter, 1980). Senior managers establish a clear strategy in terms of its competitive position (Mintzberg, 1987), understand its resources (Hamel and Prahalad, 1994) and identify its processes (Braganza, 2001; Ghoshal and Bartlett, 1995a, b). They ensure that physical and intellectual resources, skills and internal culture necessary to execute the strategy are aligned (Fuchs *et al.*, 2000).

Enterprise integration is characterised as co-operation and communication between internal teams and functions (Millson and Wilemon, 2002). Co-operation involves people in different functions creating common goals, acting cohesively and avoiding creating problems for each other (Millson and Wilemon, 2002; Pinto and Pinto, 1991). Communication refers to the two-way flow of information, horizontally between teams and across functions, and vertically between senior managers, departmental heads and people on the shop floor (Robinson and Weldon, 1993; Teigland and Wasko, 2001). Communication between people is often mediated with technology; however, this can have adverse effects on communication where, for example, organisations have evolved internal islands of information (Sarker and Lee, 1999). While the need for effective communication is recognised as vital (Newell *et al.*, 1998) evidence that it is inadequately managed in organisations is apparent (Andersson and Bateman, 1997).

Enterprise integration is considered the co-ordination of knowledge across functional boundaries (D'Adderio, 2001). Sources of knowledge can be external or internal to the organisation (Leonard, 1998) and can reside at several levels: individuals (Fahey and Prusak, 1998), group (Leonard and Sensiper, 1998), functions (Davenport and Klahr, 1998), process (Braganza *et al.*, 1999), organisation (Teece, 1998), and the industry (Leonard and Rayport, 1997). Both explicit knowledge, that which is structured, codified and encased in databases, and manuals (Nonaka and Takeuchi, 1995), and tacit knowledge; namely, behaviours, routines and people's innate skills and abilities (Nonaka, 1994; Polanyi, 1966) need to be aligned across silos (D'Adderio, 2001). Enterprise integration from a knowledge perspective recognises the inherent tensions that exist and arise where new knowledge is being created. The creation of knowledge requires people in different parts of the organisation to accept that their existing knowledge may no longer be relevant. Nonetheless, people need to feel that they can expose their tacit knowledge and that this will be treated with a degree of care. They accommodate current standardised practices with novel, non-routine practices. New knowledge impacts on practices, locally at team, department or functional levels within a strategic business unit, or globally across business units (D'Adderio, 2001). The need for change is implicit in the knowledge perspective of enterprise integration. The changes can affect the strategy, structure and behaviours across the organisation (Earl, 2001). Co-ordinating heterogeneous knowledge, asking people to share the knowledge they have built up over years and making knowledge available to all requires senior managers to break the "knowledge is power" mindset. Hence, while scholars advocate creation of a knowledge-sharing culture, in practice such initiatives are very difficult to achieve (Davenport *et al.*, 1998).

Enterprise integration is characterised as co-ordinating cross-functional processes that fulfil stakeholders' expectations (Braganza and Lambert, 2000; Hammer and Champy, 1993). The notion of cross-functional co-ordination goes beyond setting up multi-disciplinary project teams (Malone *et al.*, 1999). It impacts on the structure of the organisation (Davenport and Nohria, 1994), roles and responsibilities (Brynjolfsson *et al.*, 1997), power structures (Buchanan, 1997), workflows (Hammer and Stanton, 1999) and information technology (Guha *et al.*, 1993). The changes required to bring about enterprise integration, from the process perspective, can be radical and incremental (Jarvenpaa and Stoddard, 1998). This perspective of enterprise integration is associated with technology developments or enhancements that enable cross-functional interaction and communications (Broadbent *et al.*, 1999; Davenport and Nohria, 1994; Van Grembergen and Van Belle, 1999). Many of these IT implementations have been shown to fail (Larsen and Myers, 1999; Sarker and Lee, 1999). Consequently, many organisations have outsourced not only the IT function (Lee, 2001), but also other functions such as human resource management, administrative services and call centres (Marshall, 2001). Outsourcing functions involves senior managers taking a decision to contract out or sell the functions, assets, people, information, IT and activities, to a third-party supplier who, in return, manages the people and assets and provides a service for a financial return (Loh and Venkatraman, 1992). Outsourcing a function that forms part of a business process without understanding the relationship between the two makes integration problematic.

Attribute 2: scope

Studies of the scope of functions to be integrated have been undertaken from the perspective of one function in relation to either one or more other functions. This is exemplified by two studies. The first examines the integration between manufacturing and marketing from the manufacturing function's vantage point (Weir *et al.*, 2000). The other is a study of the research and development function's relationships with marketing and manufacturing (Sherman *et al.*, 2000). Researchers have contributed by studying functional dyads such as the marketing function's collaboration with the R&D function and vice versa (Kahn and Mentzer, 1998). Product development has been studied, as it requires cross-functional involvement (Sherman *et al.*, 2000). These studies have attempted to show the relative importance of integrating combinations of functions. The studies demonstrate that significant benefits can be gained from cross-functional integration, in terms of reductions in product development times (Sherman *et al.*, 2000), higher profits (Weir *et al.*, 2000), successful marketing programmes (Millson and Wilemon, 2002), better relationships with customers and suppliers (Narasimhan and Das, 2002) and being better able to respond to industry changes.

The integration of strategic business units involves the co-ordination of separate elements of each business unit so that efficiencies or market prominence can be achieved (Fuchs *et al.*, 2000). Strategically, SBU integration combines competencies and resources from different units to exploit emergent opportunities, develop innovative products and services or extend current strategies (Burgelman and Doz, 2001). Operationally, SBU integration aligns and co-ordinates initiatives in each unit (Herman, 2001). The lack of SBU integration is noticeable through their Web sites:

> A manufacturer discovered there were 175 different Web pages on its Web site presenting information about an important industry trend. The pages, which had been developed by various business units from around the world, presented contradictory claims and projections (Herman, 2001, p. 22).

Senior managers face obstacles when implementing SBU integration. A business unit might need to alter its strategic trajectory, which the leaders of that business unit might not be willing to do. There is also the need to share or release resources to pursue integration aims. Consequently, achieving SBU targets becomes difficult for people left behind. Internal control systems such as budgets, targets and incentive schemes prevent SBU integration (Eisenhardt and Brown, 1999). Hence, control systems need to change to ensure board's prioritise SBU integration (Burgelman and Doz, 2001).

Attribute 3: elements

Researchers have identified organisational elements that would need to be integrated. The organisation's strategy is a key element and other elements such as culture, resources and products should be aligned to it (Fuchs *et al.*, 2000). Others suggest that each function's strategy should be aligned into a single coherent document (Kahn and Mentzer, 1998). Other studies show that senior managers might have to create structures that align scarce resources such as finance, people, skills, capital equipment and management time (Burgelman and Doz, 2001; Van Grembergen and Van Belle, 1999). There is a need to integrate day-to-day routines with control mechanisms, incentive and reward systems to ensure effective cross-functional co-ordination between people (D'Adderio, 2001). Another set of elements that need to be aligned is intangible resources. They include the organisation's reputation, intellectual capital, brand and patents (Burgelman and Doz, 2001; Fuchs *et al.*, 2000).

Synthesising the literature

The literature shows that there are several characteristics of enterprise integration. Each is useful and necessary as it is improbable that an organisation can achieve and sustain enterprise integration to any meaningful extent without, for example, co-operation and communication or co-ordinating cross-functional knowledge. There are several useful options in terms of the scope of integration: involving strategic business units, functions or some combination of both. Several organisational elements can be leveraged to foster enterprise integration; these elements are self-evidently important. The need for a well articulated and communicated business strategy, for reward schemes that create unity of effort, or for clear brand values, are necessary for enterprise integration.

However, the characteristics, scope and organisational elements discernible from the literature are problematic. They form a set of theoretical options that can be used to craft an organisation's enterprise integration strategy. The options raise interesting questions: Which options should senior managers choose? On what basis should decisions be taken for or against a particular option? How should enterprise integration be managed?

The literature is missing a conceptual framework that links the array of options to the purpose of the enterprise integration initiative. Such a framework would enable managers to make decisions about structuring, resourcing, managing, and implementing enterprise integration initiatives. Without some guidelines, senior managers are left to attempt a trial-and-error approach to enterprise integration. It is perhaps not surprising, therefore, that researchers conclude that enterprise integration remains a key capability where there seems to be very little connection between practice and theory (Chikan, 2001).

The enterprise integration capabilities framework

An assumption that permeates current thinking on enterprise integration is that all enterprise integration initiatives are equally important to the organisation's strategic success. However, an initiative that is aimed at "knowledge across functional boundaries" can deliver strategic advantage across several or more modest operational efficiencies at a functional level. Similarly, "co-operation and communication" between functions can bring about new day-to-day routines that are either innovative or rather mundane. It is apparent, therefore, that enterprise integration initiatives have substantively different purposes. Thus, it is vital to understand the underlying purpose of any such initiatives.

The enterprise integration capabilities framework agrees with and extends the argument that enterprise integration

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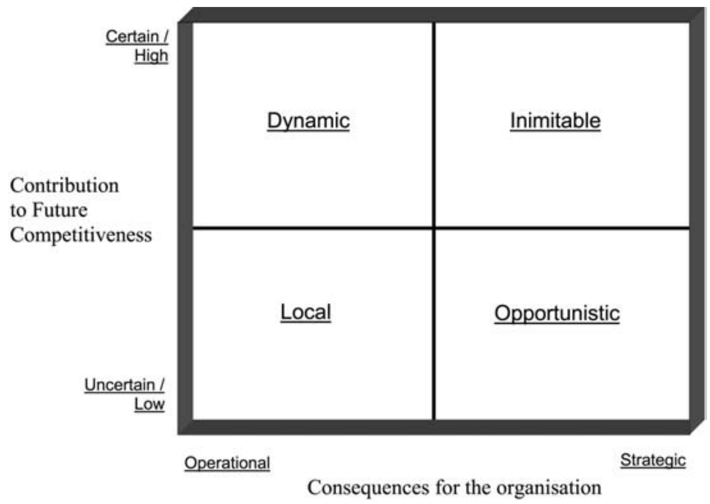
initiatives build organisational capabilities as shown in Figure 1 (Barney, 1991; Hamel and Prahalad, 1994; Johnson, 1999). Its dimensions are constructed to bring into focus the contribution a capability makes to future competitiveness (Barney, 1991) and whether the impact of the capability will be felt at a strategic or operational level (Hamel and Prahalad, 1994). Hence, an enterprise integration initiative's purpose can be understood along these two dimensions: its contribution to improving future competitiveness and its consequences on the organisation.

The framework suggests that the capability developed as an end outcome of an enterprise integration initiative will be different in each quadrant, which gets its name from the capability being developed. Locating an enterprise integration initiative in the framework is with reference to these dimensions. Enterprise integration initiatives are positioned in the bottom right-hand quadrant when senior managers are unsure of the extent to which an initiative will improve the organisation's future competitiveness or the potential benefits to be gained are uncertain. Enterprise integration initiatives are located in the top right-hand quadrant when senior managers are confident that the initiative will significantly improve the organisation's future competitive position and the consequences will affect the future strategic direction. Initiatives are sited in the top left-hand quadrant when senior managers are sure that it will lead to improved competitiveness and the consequences enhance or maintain current operational aspects of the organisation. Initiatives in the bottom left-hand quadrant are important to achieving efficiency and avoiding disbenefits in the short-term, but will have a minimal impact on improving competitiveness and the consequences will be felt at an operational level. Each quadrant is examined and illustrated with an organisational study. Qualitative data for one case was gathered from action-research carried out over a 12-month period, whereas data for the other three studies was drawn from various public sources. The examples are not intended nor are they held out to be comprehensive studies of these organisations; rather data that elucidates each quadrant of the framework is highlighted.

Figure 1
The enterprise integration capabilities framework



Implications of the framework

Inimitable enterprise integration initiatives

These develop capabilities that definitely enhance the organisation's competitive position. These capabilities are very difficult to mimic and are sustainable over time. The effects of these capabilities are to reshape the organisation's future strategic direction, aims and objectives. The impact of inimitable enterprise integration initiatives will be felt across the organisation and its industry, as the basis of competition is changed. A prime case in point is Tesco.com, Tesco plc's electronic grocery channel. It has required a high degree of integration between several functions of the group, such as the local store, warehouses, order handling, IT, marketing and finance in order to provide a complete online shopping experience to consumers. Tesco.com's online capability has enabled it to gain one million registered users and transact about 70,000 orders each week. Since its launch, it has built up sales in the region of £300 million each year and operates in four countries: the Republic of Ireland, the UK, South Korea and the USA (Tesco.com, 2002). Its entry into the highly-competitive US market was through a 35 per cent equity stake in GroceryWorks, Safeway Inc.'s e-grocery retailer. GroceryWorks operated in Texas only but will implement Tesco.com's e-shopping capability of local store deliveries to expand across the USA. Tesco.com has reinforced its parent company's market leadership position. The impact of Tesco.com's capability has been felt across the industry, as none of its UK rivals have been able to copy this strategic move (Tesco.com, 2001).

Local enterprise integration initiatives

These lead to capabilities that make a minor contribution to the organisation's competitive position. These capabilities are easily replicable and replaceable. They can be sourced from the organisation or externally. The consequences of local initiatives lead to operational efficiencies and cost reductions. The impact of local

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initiatives will be felt by a team, department or specific function. This type of initiative is exemplified by a study conducted in a major telecommunications company – referred to as Telco to preserve anonymity. Telco's provisioning function consists of seven departments; each plays a part in fulfilling a customer order. According to the function's director, departmental heads "were at war with each other" when he joined. As a result, 90 per cent of orders were delivered late, or in the parlance of the organisation, were classified "DOA" for dead on arrival. The director set out to improve the provisioning function's performance so that 98 per cent of orders were delivered on time. He identified processes and knowledge requirements that people in each department said they required, changed the bonus scheme such that departmental heads received 25 per cent of their bonus if their department's targets were achieved, a further 25 per cent of their bonus if departments either side of theirs in the process achieved their targets, and the remaining 50 per cent of the bonus if the function's overall target of 98 per cent on time deliveries was met. Within a matter of months, departments were meeting their targets and the provisioning function achieved its performance turnaround. However, when this initiative is considered in terms of the whole organisation, its contribution to competitiveness was marginal and its consequences were at an operational level. In spite of the capabilities developed by the provisioning function, the organisation's wider competitive position has collapsed for a host of industry and financial reasons.

Dynamic enterprise integration initiatives

These deliver capabilities that are specifically identified as being necessary to maintain the organisation's current competitive position. The consequences of these enterprise integration initiatives are to ensure capabilities are aligned with and maintained to the same levels as key competitors. This continuous alignment and re-alignment is in terms of the quality of the capability and the ways in which the capabilities are combined to avoid losing competitive advantage. The impact of these enterprise integration initiatives will be felt across the organisation. The case of Marks & Spencer provide interesting insights into this type of initiative. They lost their competitiveness as new niche players entered the clothing market, focused on specific consumer segments, tailored products to meet their tastes. M&S lost sight of its customers, becoming product-push rather than customer-pull oriented. Inter-departmental rivalry was rife, leading to very poor co-ordination between departments (Bevan, 2002). However, a new executive chairman was appointed and made internal changes, particularly in the head office, to ensure better integration so that the organisation can, once again, compete effectively. In effect, M&S are developing capabilities that deteriorated over a period of time; bringing their capabilities in line with competitors.

Opportunistic enterprise integration initiatives

These create capabilities that have a high degree of uncertainty in terms of their contribution to the organisation's future competitive position. The capabilities developed by these initiatives may be vital to future success but then again may not be. The consequences of opportunistic enterprise integration initiatives are whether capability is proven to be critical to future strategic success, its effects can be far reaching. On the other hand, where these initiatives develop capabilities that do not contribute to maintaining the organisation's current or future competitive position, they should be stopped. FirstDirect, the 24-hour, 365 days a year telephone and Internet bank is a good case example of an opportunistic initiative. The concept of a telephone bank was formed by a handful of people from several different departments in what was then the Midland Bank (now HSBC). This cross-functional team commissioned significant research to understand, among other things, customers' behaviours, wants and interactions with their bank (Mayers, 1992). The team analysed the findings and developed the concept to a stage where they were able to demonstrate to the Midland main board that the potential for considerable competitive success in terms of being first to market. Hence, they were given the funds to develop a full banking capability (Ashworth, 1997).

Managing enterprise integration initiatives to achieve their purpose

The enterprise integration capabilities framework shows that enterprise integration initiatives are not all the same: because they have different purposes. Hence, when planning an enterprise integration initiative its design should match its purpose. Returning to the attributes of enterprise integration drawn from the literature, we can consider the managerial implications in relation to the four types of enterprise integration initiatives.

Inimitable integration initiatives require clarity of future strategic direction. This involves setting a new strategic direction and changing the very basis of competition in the organisation's sector or industry. This type of initiative requires organisations to understand their customers' needs and reflect this in their future product and market mix. This includes defining new customer segments, value propositions and service offerings. Inimitable initiatives establish new objectives and goals that the senior management team recognise, accept and share across the functional silos. New information flows are established, with people in different functions contributing their knowledge. Internet technologies can be particularly effective in enabling a significant degree of knowledge co-ordination across functions, where tacit knowledge is shared and developed to create new knowledge. Inimitable initiatives require tightly coupled processes that are aligned to stakeholders' expectations and the new strategic direction. Each process acts as the co-ordinating mechanism for cross-functional targets, roles and responsibilities. This type of initiative calls for Internet technology-based systems that are properly integrated across the organisation and are aligned to the processes. The scope of inimitable initiatives includes virtually all the functions in the organisation. The scope might well extend to other SBUs with resources being re-allocated and SBU specific targets and goals being re-prioritised. Several organisational elements are affected by these initiatives. Senior managers need to be prepared to change elements such as reward schemes, culture and day-to-day routines. Inimitable initiatives that are mismanaged pose risks to organisational elements such as reputation, brand and intellectual capital.

Opportunistic integration initiatives enable the creation of new capabilities. They require clarity of the organisation's current strategic direction and use this as the starting point for identifying and evaluating options for new strategic directions. These options are developed into tangible goals and objectives. Opportunistic initiatives aim to prove in the shortest space of time which option achieves optimal strategic advantage. This type of initiative requires high levels of tacit knowledge to be shared. People managing opportunistic initiatives need room for creativity and openness to learning. People should feel able to question and discard "sacred cows" that impede future advantage. Because opportunistic initiatives set out to create future capabilities, they have little immediate impact on current day-to-day cross-functional processes and enterprise-wide technology. However, the outcomes of such initiatives might reconfigure entire business processes and introduce Internet technologies to ensure integration. The scope of this type of initiatives will span all functions in the organisation, although some will be more intensively committed than others. Opportunistic initiatives can span SBUs as people, equipment, premises and other resources are brought together to create new capabilities. In terms of organisational elements, opportunistic initiatives have little direct impact on any element while ideas and options are being evaluated. However, where senior managers pursue an option to full implementation, several organisational elements will be affected, some profoundly.

Local integration initiatives maintain or enhance levels of integration at team or departmental levels. These initiatives involve standardised linkages, which can be turned into a set of procedures. Communication and information flows are systematic. This type of initiative is weighted towards explicit knowledge that can be specified, codified and structured. Local initiatives would rarely lead to new knowledge being created. Such initiatives focus on one or more activities in a small number of functions, rather than an entire process. These initiatives co-ordinate activities to meet the expectations stakeholders value least. Local initiatives are unlikely to lead to enterprise-wide systems being developed. Any systems enhancements must be shown to deliver tangible benefits through improved co-ordination. Bespoke applications for any department or team should be avoided. Local initiatives are typically scoped on an intra-functional basis. However, there are benefits from sharing good practice across functions and SBUs. Local initiatives rarely require people and resources to be re-allocated across SBUs. A subset of organisational elements will be affected by local initiatives. These include day-to-day routines, incentive schemes and the culture of the function(s) included in the initiative. Local initiatives have a marginal effect on elements such as brand, reputation and patents.

Dynamic integration initiatives ensure the organisation has capabilities to fulfil its current strategic direction. This requires a clear strategy and objectives that are quantified and prioritised. These establish improvements to business critical issues such as customer service, products and value. The capabilities developed by dynamic initiatives are gauged relative to the competitive environment in which the organisation operates: capabilities should be equal or better than competitors. People in different functions are able to agree quickly to changes to goals and objectives and communicate these across the organisation. Cross-functional information flows are effective at all levels of the organisation. Dynamic initiatives require people to share explicit knowledge across functional boundaries. Tacit knowledge in different areas is valued and developed. However, dynamic initiatives can lead to people changing knowledge flows to meet changing external demands. These initiatives re-align cross-functional processes to remain attuned to changing stakeholder expectations. Such initiatives recombine people, systems and resources. Dynamic integration initiatives suggest the use of enterprise-wide systems than can be based on Internet technologies that support entire processes rather than activities or functions. The scope of dynamic initiatives will be across all functions and require high levels of co-ordination. Dynamic initiatives affect many organisational elements. Some of these might be changed significantly to maintain the organisation's alignment to external environmental factors.

Summary

This paper sets out a framework that enables practitioners to focus their enterprise integration efforts to exploit capabilities. The framework requires business leaders to consider the capabilities they want to develop in terms of competitiveness and organisational consequences. Where an organisation wants to develop capabilities that revolutionise its industry, overturn the prevailing basis of competition and create a unique competitive space, it must pursue an inimitable enterprise integration initiative. In case the organisation wants to develop new, unproven capabilities, it should organise an opportunistic integration initiative. An organisation must avoid its capabilities degenerating to the point where they fall behind competitors and are unable to sustain growth; in which case, organisations must engage in a dynamic integration initiative. Organisations carry out local integration initiatives to ensure that their operations are efficient and that costs and wastage are being prevented. This approach to enterprise integration requires senior managers to consider the purpose of projects such as Internet Technologies, ERP systems, mass customisation and supply chain management, which require cross-functional integration, prior to their launch and then manage these project accordingly. The paper challenges conventional thinking: that all capabilities are the same. It suggests that there are different types of capabilities and that any one organisation should develop a portfolio of enterprise integration initiatives to ensure it has the capabilities to achieve sustained profitable growth.

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Application of established and emerging B2B e-commerce technologies: Australian empirical evidence

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Internet,
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Abstract
Draws on data collected from 553 Australian companies and focuses on differences in the adoption of established (e.g. EDI) and emerging (e.g. the Internet) technologies for the management of supply chains. Overall, the use and adoption of existing technologies can be characterised as restricted, apparently costly, and perceived to be limited in terms of potential benefit. On the other hand, adoption and use of emerging technologies such as the Internet would appear not to be suffering from these traditional restrictions. The limitation of EDI to large companies is not evident in the use and adoption of the Internet, neither is the limitation on use at the manufacturing end of the supply chain. Concludes that there is evidence that the adoption of emerging Internet-based technologies for the management of supply chains does not appear to be subject to many of these constraints. However, it is not clear whether this ease of adoption will mean that the benefits will also flow as easily to these companies.

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Introduction

Despite the apparent opportunities for improved supply chain management and performance (Forrester, 1958, 1961; Bhaskaran, 1998; Ballou *et al.*, 2000; Belyea, 2000; Cachon and Fisher, 2000; Chen *et al.*, 2000), the adoption of technology to enable the more efficient management of supply chains has been slow, with some of this technology (e.g. EDI) having been available for more than 30 years (Johnston and Mak, 2000). Burnell (1998) quotes KPMG research from 1998 in the USA, where it was found that although 92 per cent of retailers surveyed were sharing information with customers and suppliers, 79 per cent were using fax or paper-based means to do this. Carter and Hendrick (1997) also cite research conducted by the Centre for Advanced Purchasing Studies, in the USA, who found in 1996 that only 13 per cent of purchase orders across 25 industries (493 companies) are transmitted via EDI. This is despite other research indicating that the contribution of the cost of paperwork to the final price of a product can range from between 3.5 per cent to 15 per cent (Ojala and Suomi, 1992). Part of the explanation for the slow take up of this technology, and its restricted application in small/medium companies has been attributed to the cost and difficulty of implementation. The cost and complexity of EDI implementation has been covered extensively in the literature of supply chain management, electronic commerce and information technology implementation (Adams, 1997; Barber, 1997; Barua and Lee, 1997; Bytheway and Braganza, 1992; Cash and Konsynski, 1985; Hart and Saunders, 1997; Iacovou *et al.*, 1995; Koloszyk, 1998; Lee and Clark, 1999; Ramamurthy *et al.*, 1999; Rassameethes and Kurokawa, 2000). Recent rapid changes in technology have had both positive and negative impacts in this context. On the one hand, they provide further opportunities for improved supply chain performance. On the other hand, this increasing rate of change promotes obsolescence. Systems that were recently "state of the art" can become outdated legacy systems quite quickly (Froehlich *et al.*, 1999; Hewitt, 1999). The ability of the Internet to overcome problems common to previously used networks could be a major facilitator of this process. Johnston and Mak (2000) see the Internet and EDI being used in conjunction. In this sense the Internet would be used as a means of enhancing current systems and technologies, rather than being just a cheaper alternative to EDI. Chan and Swatman (2000) have also identified, through a case study conducted in one of Australia's largest companies, that the initial motivation for EDI adoption may be cost reduction and the pursuit of internal efficiencies. In this particular case, however, there was a progression over time from this internal focus, to the use of technology for promotion of supplier partnerships and improved customer service. Recent research has indicated that although the potential benefits are understood, there appear to be many reasons for a lack of speed in application. A survey of 400 e-commerce managers provides some insight into the nature of these problems (Warehousing Management, 2000, p.7):

> . . . the single biggest bottleneck to widespread adoption of B2B e-commerce is manual "enablement", or the process of preparing a company, its internal systems and its trading partners to begin conducting transactions over its trading networks.

The survey finds that:

- 56 per cent of respondents conduct business-to-business (B2B) transactions with less than 25 per cent of their trading partners;

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- 77 per cent perform less than 15 processes electronically with partners;
- 45 per cent perform less than 5,000 electronic transactions a month.

Australian research has identified a range of issues, particularly relevant to small and medium enterprises (SMEs), that shed further light on these issues (National Office for the Information Economy/Telstra Corporation, 2000). In this case, it was found that only 28 per cent of companies connected to the Internet used it for procurement of goods and services. These results are in line with some research from the USA that found that a high proportion of SMEs saw EDI implementation as simply adding to the cost of doing business (Raymond and Bergeron, 1996). Reasons given for this reluctance included preference not to deal directly with a supplier and security concerns. Respondents also indicated a range of reasons why they might be reluctant to move into electronic commerce:

- Moving onto the Internet could lead to uncontrolled growth.
- Fear of alienating intermediaries.
- Satisfaction with current business arrangements.
- Concern about levels of understanding of the technology.
- Time and expense of reengineering processes.
- Fear their products would not be suitable for trading via the Internet.

Despite this apparent reluctance, the Internet is predicted to provide a medium for the more cost-efficient transfer of EDI documents between trading partners (Abcede, 1997; Adams, 1997; Barber, 1997; Johnston and Mak, 2000; Mohta, 1997; Segev *et al.*, 1997; Truman, 2000), and some have predicted cost reductions of up to 80 per cent (Barber, 1997). One of the implications of this openly accessible, cheap and rapidly growing global network is the potential for businesses to substantially increase their reach. Recent Australian Government research indicates that more than 50 per cent of small businesses, 90 per cent of medium businesses, and all large companies are accessible via the Internet. It is also estimated that well in excess of 100 million users are online worldwide (National Office for the Information Economy/Telstra Corporation, 2000), and that in the year 2001 Internet users could transact business worth as much as $US200 Billion (Sim, 2000). The model of an Internet-enabled "virtual supply chain" has been developed and implemented by companies such as Dell Computer and Cisco Systems. Jutla *et al.* (1999) describe this as the "manufacturer business model". They differentiate it from other forms of Internet-enabled e-commerce business models on the basis that marketing and distribution are part of the company's operations, and production planning is supported by the virtual supply chain and product demand forecasting. Major benefits of this approach are listed in the literature as increased visibility of real customer demand patterns (Lee *et al.*, 1997, Coleman and Austrian, 2000), significant decreases in delivery lead times (McCormack, 1999), information sharing and greater depth of relationships between trading partners (Manasco, 2000), improved visibility upstream along the chain to determine inventory availability (Radjou, 2000), and the development over time of a core competence in low cost customised manufacturing and fulfilment (Westhead *et al.*, 2000). The issue of visibility has also gone beyond just an awareness of what is happening with selected suppliers and/or customers (such as those with whom a company can afford to maintain EDI links), to a potentially broader network of suppliers, customers, warehouses and manufacturers (Coleman and Austrian, 2000).

The research presented in this paper was undertaken against this background of opportunity for improvement and an apparent slow rate of adoption of some of the technologies. Given that there appear to be both impediments to the adoption of B2B e-commerce-enabling technology, and opportunities for competitive advantage from their adoption, what is the level of adoption of emerging technologies (e.g. the Internet) compared to that of existing technologies (e.g. EDI)? Are organizations adopting Internet-based technologies with the same cautious and slow approach that has characterised use of EDI? Can adopters of both existing and emerging technologies be characterised as belonging to the same demographic groupings (e.g. large companies adopting EDI due to high cost)? Are the apparent impediments to adoption and use of existing technologies (e.g. EDI) still applicable to the use of the Internet? Do a broader range of companies appear to be aware of the potential benefits of the emerging Internet-based technologies?

Methodology

Background

A survey yielding 553 responses from Australian companies was conducted for the purpose of identifying and confirming some of the major issues relating to the implementation of B2B e-commerce practices. The sample was drawn from organizations who are members of the European Article Numbering Association (EAN) Australia. As such, these organizations have been using established e-commerce enabling technologies for some time. A total of 11,000 organizations (the full membership of EAN Australia) were sent survey questionnaires incorporated into a quarterly newsletter. A subsequent survey of non-respondents was also conducted, covering 1,707 member organizations. This non-respondent survey indicated that only 26 per cent of companies received the newsletter and found the survey inside. This survey also provided evidence to the effect that the membership database was carrying a 15 per cent error rate (wrong company name, address changed, etc.). A total of 925 further surveys were sent out to companies involved in the non-respondent survey. As a result, the true sample size is estimated at 3,350 member organizations. There were 554 responses received, an estimated response rate of 16.5 per cent. Comparison of the results from both the member survey and the non-respondent survey indicated that the 554 respondent members were representative of the total membership base. The two variables used for comparison were primary business activity (or industry) and the number of people employed by the organization. The Chi-square and *T*-tests used indicated that there were no significant differences between the two groups on these two variables. Confidence in the generalisability of the results is further supported by the number of responses (554), which is in excess of the number required from a sample of 11,000 (375) or, alternatively, for the estimated sample of 3,350 (346) (Krejere and Morgan, 1970).

Methods of analysis

The focus of this paper is on two sections of the survey containing questions relating to the use of various enabling technologies, and a third covering the perceived cost benefit differential for the implementation of established technologies. The first of these relates to the use of EDI and comprised two sets of questions. The first of these related to the extent of use of various EDI applications and is contained in Table I.

The second set of questions covered six of these seven applications and asked respondents to indicate which of these provided significant benefit to their organization. Table II contains this group of questions.

The second section of the survey related to the uses and functions of Web sites and comprised of two separate groups. The first of these related to operation of current and intended future Web sites, and is contained in Table III.

The second group of Internet-related questions related to the extent of usage of the Internet, and is contained in Table IV.

The final question related to the perceived cost vs. benefit differential for implementation and use of existing technologies, and is contained in Table V.

These five groups of questions were analysed using a range of statistical techniques including ANOVA, *T*-tests, cross-tabulation and Chi-square testing. They were also in some cases aggregated on the basis of simple frequencies and analysed in comparative graphical formats. Three major demographic variables were used for comparison of the results and to provide greater depth to the analysis. These were company size (based on the number of employees in Australia), industry sector (manufacturing, wholesale distribution and retail), and ANZSIC Code (an industrial classification system developed jointly by the Australian Bureau of Statistics and the New Zealand Department of Statistics – the international equivalent being the ISIC standard). Table VI contains both an abbreviated and extended description of each of the ANZSIC code categories used in the research.

Data analysis

Extent of use of established technologies

The following proportions of companies using EDI for various applications were recorded: incoming sales orders – 30 per cent, advanced shipment notices (ASNs) – 25 per cent, remittance advice – 26 per cent, invoices 25 per cent, evaluated receipts settlement (enablement of electronic funds transfer transactions) – 20 per cent, point of sale (POS) data – 22 per cent and purchase orders to suppliers – 19 per cent. Company size was found to be correlated with use of all of these EDI applications (see Table VII).

Larger companies were found to be more likely to be using EDI applications than smaller ones and, in particular, companies employing more than 1,000 employees indicated very high comparative usage (see Figure 1).

Significant differences were also found between the extent of use of EDI applications when compared across different industry sectors. For five (5) of the seven (7) applications significant differences ($p < 0.05$) were found between the groups, with the retail organizations indicating a higher level of usage overall. Manufacturers lagged behind the retail and wholesale distribution sectors on all seven applications, while the "other" category (comprising construction, government, hospitality and health care services) reported very low levels of usage. Figure 2 presents these results.

The EDI application reported to be of most benefit for respondent organizations was found to be incoming sales orders, with 68 per cent saying it delivered significant benefits. The application reported to deliver the lowest level of benefit was EDI POS data (41 per cent), an interesting finding in light of the emphasis in the literature on the potential benefits of more timely demand information for supply chain partners (Truman, 2000; Unal, 2000; Upin *et al*., 2000; Maltz and Srivastava, 1997; Lee and Clark, 1999; Lee *et al*., 2000; Kaufman *et al*., 2000). Table VIII shows these results.

When these results were compared on the basis of industry, it was found that there was a difference in perception of benefits derived from use of ASNs between manufacturers and organizations from the wholesale/retail sectors. It was found that manufacturers recorded significantly lower levels of benefit ($p < 0.05$) from this use of EDI. There were no significant differences found in perceived benefits when examined on the basis of company size.

Usage of EDI when compared on the basis of ANZSIC Code was found to be lowest in the printing, publishing and recorded media group, and highest in the textile, clothing and footwear (TCF) sector. The high comparative usage in the TCF group reflects a large government investment in this sector during the 1990s to combat the increase in competition resulting from lowered tariff barriers. Figure 3 shows this comparative usage.

Perception of cost/benefit

Highly significant differences ($p < 0.001$) were found on the basis of perceived costs and benefits as a result of implementation. The data analysis indicated that costs increased as implementation is extended, but there is a significant divergence between cost and benefit as this process unfolds. This divergence is further confirmed by the correlations found between cost, benefit and extent of implementation of existing technologies. Both were highly significant ($p < 0.01$), but they varied greatly in strength (0.177 for cost and 0.357 for benefit). This indicates a clear perception of benefit increasing significantly in relation to cost as implementation is extended along a company's supply chain. No significant difference was found between perceptions of cost for different industry categories. There was, however, a highly significant difference ($p < 0.001$) in perception of benefits. The retail sector recorded the highest level of benefit, while the "other" category and manufacturing recorded the lowest. A similar picture emerges for company size, with larger companies believing there to be a bigger differential between cost and benefit (i.e. benefit outweighing cost) than smaller companies. Figure 4 displays the results for perception of cost benefit by industry sector, and shows clearly the escalating perception of benefit as against cost the further along the supply chain (and perhaps the closer to the end user) the company is. It is also interesting to note that analysis of this data by ANZSIC code indicates that the group with the lowest expectation of improved business performance as a result of

Table I
Questions relating to the extent and use of EDI

Techniques and methodologies	Not at all	To some extent			To a very large extent
Receive incoming sales orders via EDI	1	2	3	4	5
EDI advance shipment notices (ASN)	1	2	3	4	5
EDI remittance advice	1	2	3	4	5
EDI invoices	1	2	3	4	5
Evaluated receipts settlement (for enabling EFT)	1	2	3	4	5
EDI sales/stock on hand/stock on order data	1	2	3	4	5
Transmit purchase orders to suppliers via EDI	1	2	3	4	5

Table II
Questions relating to the extent of value contributed by EDI

Which of the EDI enabled transactions below provide a significant benefit for *your* organisation (tick all appropriate boxes)?

1 EDI advance shipment notices	2 EDI invoices	3 EDI point of sale data
4 EDI remittance advice	5 Incoming sales orders via EDI	6 EDI purchase orders to suppliers

implementation is the TCF group. As discussed, this group records the highest levels of EDI usage, and have had substantial assistance from government in recent times to promote the use of a range of supply chain management-enabling technologies.

Comparative uses of the Internet

There was little difference found in use of the Internet based on either company size or industry, except for the use of e-mail. In this case, smaller organizations and manufacturers were found to be significantly correlated with lower uses of e-mail, and larger organizations from retailing with higher levels of use (0.167 at $p < 0.01$ and 0.108 at $p < 0.05$, respectively). On the other hand, extent of implementation of established technologies (e.g. EDI) was found to be significantly (all at $p < 0.01$) correlated with use of the Internet on all six dimensions tested. Table IX contains the Pearson correlation for each dimension.

These results indicate that organizations currently using the established technologies are also using the emerging technologies to a higher degree. There is also an indication that the relationship between company size and industry sector and the use of established technologies (e.g. EDI) does not hold for the use of the Internet, and that the easy access to and use of Internet technologies is a potential new enabling factor in the management of supply chains. This is particularly evident when the use of EDI is compared to the use of Internet technologies across ANZSIC code groupings. In this comparison there is found to be very little difference between each ANZSIC sector in terms of use of Internet technologies for trading and exchanging information between trading partners. This is in stark comparison to the use of EDI, on which basis the groups are sharply differentiated. Figure 5 shows this comparison.

Of particular interest here is that the printing, publishing and recorded media sector are the highest users of the Internet, when they were the lowest users of EDI; in fact, recording almost no usage of that established technology. This pattern is repeated for other low EDI users such as medical and pharmaceutical products, and food, beverage and tobacco.

Table III
Questions relating to operation of current and intended future Web sites

Does your organisation currently have an operational Web site?	
Yes	☐
No	☐
If Yes – what functions does the site serve?	
Product information/catalogues	☐
Public relations	☐
Customer service interface	☐
Direct marketing (i.e. to end users)	☐
General company information	☐
Business-to-business trading with suppliers	☐
Business-to-business trading with customers	☐
Other (please specify) ______________________	
If No – does your organisation plan to implement a Web site?	
Within 12 months	☐
1-2 years	☐
Some time in the future	☐
Not at all	☐
If you do plan to implement – what functions will the site serve?	
Product information/catalogues	☐
Public relations	☐
Customer service interface	☐
Direct marketing (i.e. to end users)	☐
General company information	☐
Business-to-business trading with suppliers	☐
Business-to-business trading with customers	☐
Other (please specify) ______________________	

Comparative functions of Web sites

When the replies to the following question from the survey are compared based on both company size and industry: “Does your organization currently have an operational Web site?”; it becomes apparent that there is a strong relationship between having a current operational Web site and company size. Of the 46 per cent of respondents stating that they did have Web sites, larger organizations indicate a higher likelihood than do smaller ones with the correlation being 0.246 at $p < 0.001$. By way of contrast, there is no significant relationship recorded between industry sector and the operation of a current Web site, indicating that organizations in all sectors are using the Internet to at least provide an online presence. Figure 6 illustrates the relationship between company size and having a currently operational Web site.

This relationship does not hold, however, for plans to implement Web sites. When the answers to the following question from the survey are compared: “If *no* – does your organization plan to implement a Web site?”; there are few if any significant differences found. In this case, there is a universal bias toward developing and implementing an Internet presence across all groups. In fact, the data indicates that although a higher proportion of larger organizations are planning to implement within the next 12 months, there is little difference between the micro (one to four employees) and Macro (> 200 employees) sectors in terms of implementation intentions over the longer term. Only 17 per cent of the micro group indicated they will never establish a Web site, compared to 14 per cent of the macro group. Significance testing of this data also indicated no relationship between company size and plans to implement Web sites (see Table X for the percentage breakdown of responses).

Examination by ANZSIC code further highlights this trend toward Web site implementation. When a comparison between ANZSIC code groups is made on the basis of both existence of current Web sites, and intention to implement in the future, it is apparent that there is a common intention to adopt Internet technologies further. The group showing the lowest level of intention for future implementation was the agriculture sector, but even in this case 60 per cent of respondents indicated an intention to implement a Web site some time in the future. Figure 7 shows this comparison.

The results also indicate that organizations with current Web sites have tended to use them more for establishing a presence, providing product information, general company information and public relations. They have placed less emphasis on transactional issues such as customer service, direct marketing and B2B dealings with suppliers and customers. This is contrasted with organizations planning to implement Web sites, who appear to be placing an equal (or, in some cases, greater emphasis) on commercial transactions. This is apparent when the data is analysed both on the basis of company size and industry, with the emphasis in both cases being placed on creating a "presence" rather than on transacting business via current Web sites. What is also clear is that the intention to use the Internet in the future to trade with both customers and suppliers is a commonly shared objective that is not dependant on company size, industry or ANZSIC code category. Figures 8 and 9 illustrate this from the viewpoint of industry sector.

Of particular interest is the fact that although there is still a gap between the groups in the extent to which they plan to use sites for B2B transactions, customer service, etc., they are all moving together in this direction. This is in contrast to other established technologies such as EDI tested through the survey, where the difference between the groups is significantly different on a wide range of dimensions. The convergence in this area of technology adoption is an indication of a potential shift in perception that could have an impact on future application of emerging technologies for the management of supply chains.

Table IV
Questions relating to the extent of use of the Internet

	Not at all	To some extent			To a very large extent
How regularly do you (personally) use the Internet for conducting company business as part of your functional role in the organisation?	1	2	3	4	5
Indicate the extent of usage for the following objectives:					
Collecting general information	1	2	3	4	5
Purchasing	1	2	3	4	5
Customer service	1	2	3	4	5
E-mail	1	2	3	4	5
Order fulfilment	1	2	3	4	5
Other (please specify) ______					

Table V
Question relating to perceived cost versus benefit of existing technologies

In your view, where on the following scales do the implementation of existing systems fit in terms of their potential cost/benefit to *your* organisation

Low cost	1	2	3	4	5	High costs
Low benefit	1	2	3	4	5	High benefit

Table VI
Definitions of ANZSIC codes

Abbreviation	Full description
Met. products	Metal products
Med. & Pharm. Products	Medical and pharmaceutical products
PP & R Media	Printing, publishing and recorded media
W & P Products	Wood and paper products
Food Ret.	Food retailing
Oth. Manuf.	Other manufacturing
F B & T	Food, beverage and tobacco
Agric.	Agriculture
Other	Miscellaneous
PHG Wholes	Personal and household goods wholesaling
TCF	Textiles, clothing and footwear

Discussion

The analysis provides some insight into the adoption patterns of technologies that have been in use for some time, and of those that are emerging such as the Internet. It is apparent that the adoption of EDI in Australian companies has been limited to, in the most part, larger companies, and that this is in part due to a perception that the cost benefit differential is greater for both larger companies, and for companies at the retail end of the supply chain. This perception of a growing differential (i.e. between cost and benefit for established technologies), as one moves along the chain of supply toward the customer, is striking, and points to impediments in the ability of companies separated from the end user in both time and space to seeing the potential for investing in supply chain management technologies. It is also apparent that the sectors of industry (i.e. by ANZSIC code) that have been most active in implementing EDI technologies, have been those that have received significant financial and in kind assistance from government authorities (e.g. TCF manufacturers). At the same time, this group report the lowest levels of expectation of improved business performance as a result of implementation, perhaps pointing to a more realistic outlook as a result of accumulated experience in use of EDI, and further highlighting the cost and complexity of implementation noted in earlier studies (Adams, 1997; Barber, 1997; Barua and Lee, 1997; Bytheway and Braganza, 1992; Cash and Konsynski, 1985; Hart and Saunders, 1997; Iacovou *et al.*, 1995; Koloszyk, 1998; Lee and Clark, 1999; Ramamurthy *et al.*, 1999; Rassameethes and Kurokawa, 2000). Overall, the use and adoption of existing technologies can be characterised as restricted, apparently costly, and perceived to be limited in terms of potential benefit. On the other hand, adoption and use of emerging technologies such as the Internet would appear not to be suffering from these traditional restrictions. The limitation of EDI to large companies is not evident in the use and adoption of the Internet, neither is the limitation on use at the manufacturing end of the supply chain. What is also of particular interest is the way all types of organizations in all sectors appear to either have adopted, or be planning to adopt the Internet as a means of facilitating trade with both customers and suppliers. Only a very small percentage of organizations indicate no intention to set up a Web site, and there is a clear trend toward using the Internet to transact business with trading partners rather than just having an online "presence". This finding provides some support for the proposition that the Internet will provide a medium for the more cost-efficient transfer of documents between trading partners (Abcede, 1997; Adams, 1997; Barber, 1997;

Table VII
Correlation between company size and EDI applications

EDI application	Correlation	Significance
Incoming sales orders	0.209	$p < 0.01$
Advanced shipment notices (ASNs)	0.182	$p < 0.01$
Remittance advice	0.203	$p < 0.01$
Invoices	0.169	$p < 0.01$
Evaluated receipts settlement	0.227	$p < 0.01$
Point of sale (POS) data	0.222	$p < 0.01$
Purchase orders to suppliers	0.310	$p < 0.01$

Figure 1
Extent of usage of EDI enabled technologies by company size

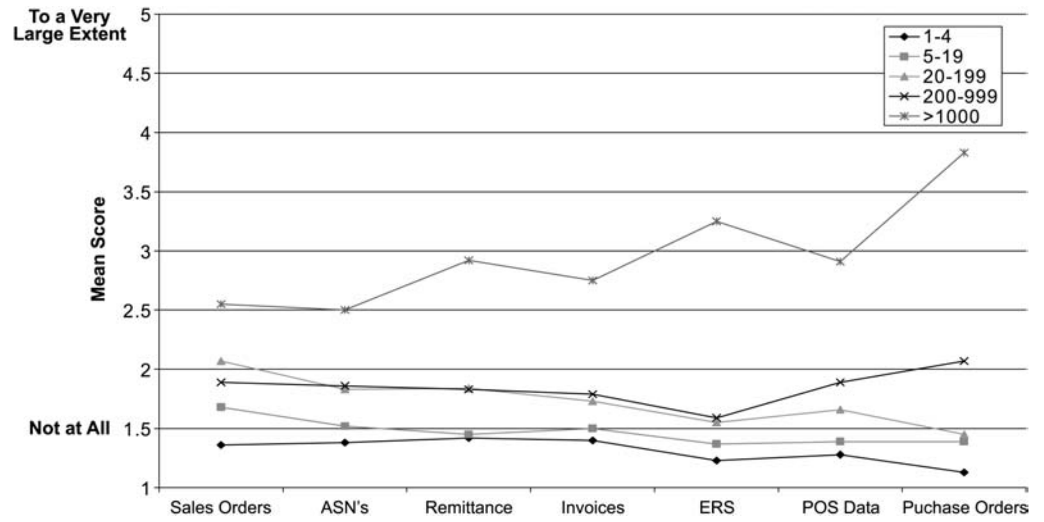


Figure 2
Comparative usage of EDI by industry

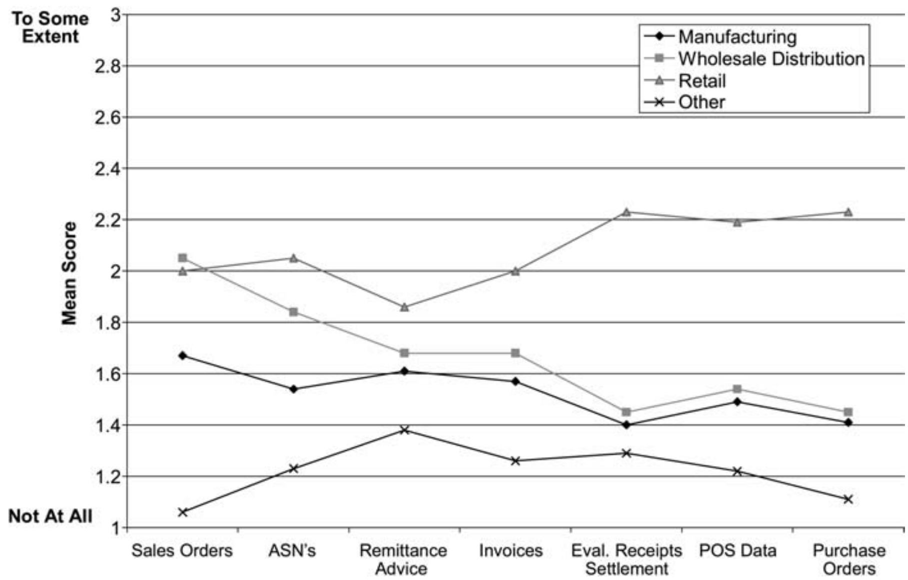


Table VIII
Comparative benefits of EDI

EDI application	% reporting significant benefit
Advanced shipment notices (ASNs)	55.2
Invoices	53.8
Point of sale (POS) data	42.1
Remittance advice	53.4
Incoming sales orders	68.1
Purchase orders to suppliers	48.9

Johnston and Mak, 2000; Mohta, 1997; Segev *et al*., 1997; Truman, 2000). This trend is particularly noticeable when the data is analysed by ANZSIC code. In this case, the previous patterns of adoption of EDI (based on government funding of vulnerable sectors such as TCF) are replaced with a universal adoption (or stated intention to adopt) of Internet technology. Industry sectors from agriculture through to food retailing (in other words, both ends of the supply chain)

Figure 3
Comparative use of EDI by ANZSIC code

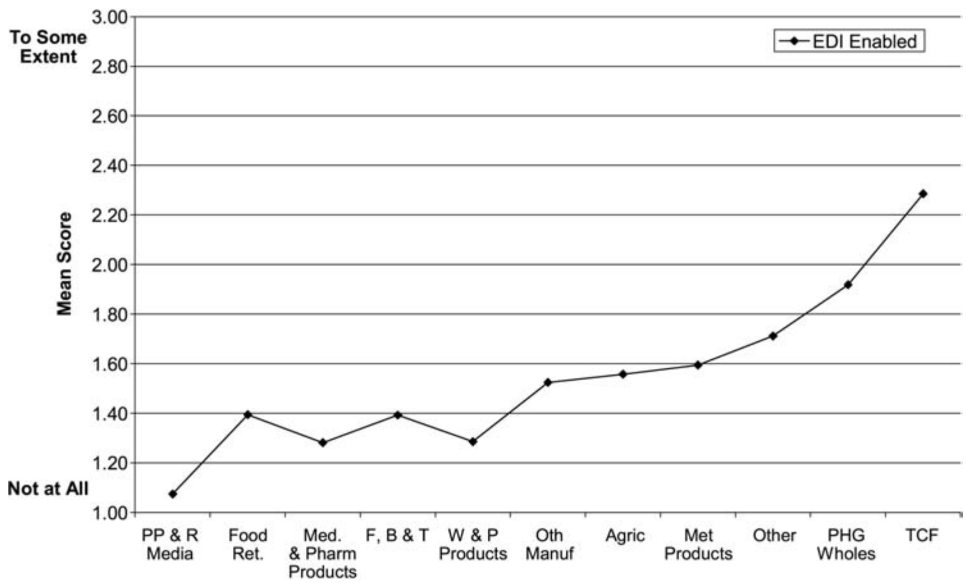
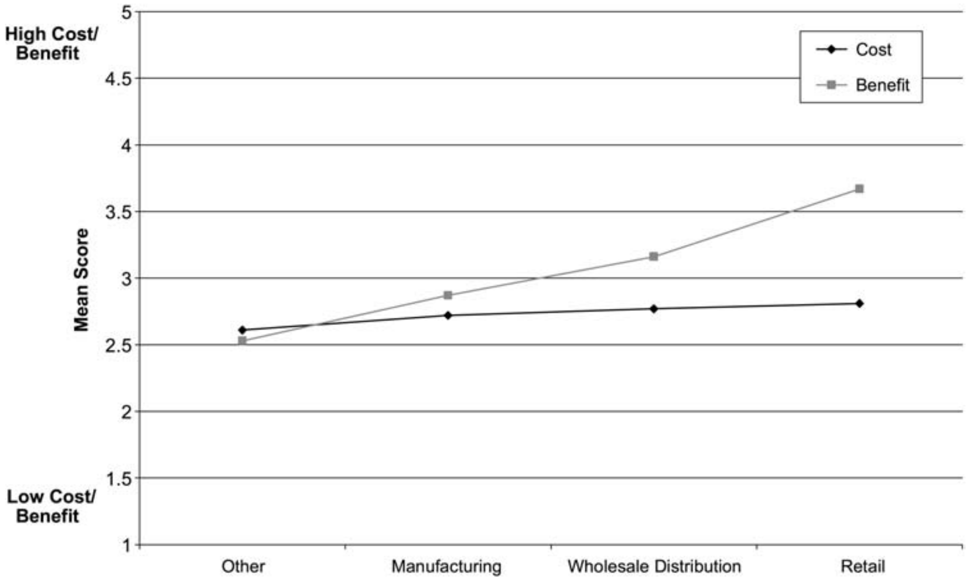


Figure 4
Cost/benefit comparison by industry type



are either using the Internet, or plan to use it in the future for trading with customers and/ or suppliers. Company size is also no longer an impediment, with even "micro" organizations (employing one to four people) reflecting this same trend.

Table IX
Pearson correlations for use of the Internet by extent of implementation of established technologies

Regular use for company business	Collecting general information	Purchasing	Customer service	E-mail	Order fulfilment
0.241	0.144	0.242	0.248	0.164	0.296

The conclusion that can be drawn is that there is evidence that the adoption of emerging Internet-based technologies for the management of supply chains does not appear to be subject to many of the constraints that EDI and other established technologies have been subject to. What is not clear is whether this ease of adoption will mean that the benefits will also flow as easily to these companies. Companies using established technologies such as EDI report generally significant benefits, but at a high comparative cost in some industry sectors (e.g. manufacturing). There is some indication that the cost of implementing

Figure 5
Comparison between usage of EDI and the Internet by ANZSIC code

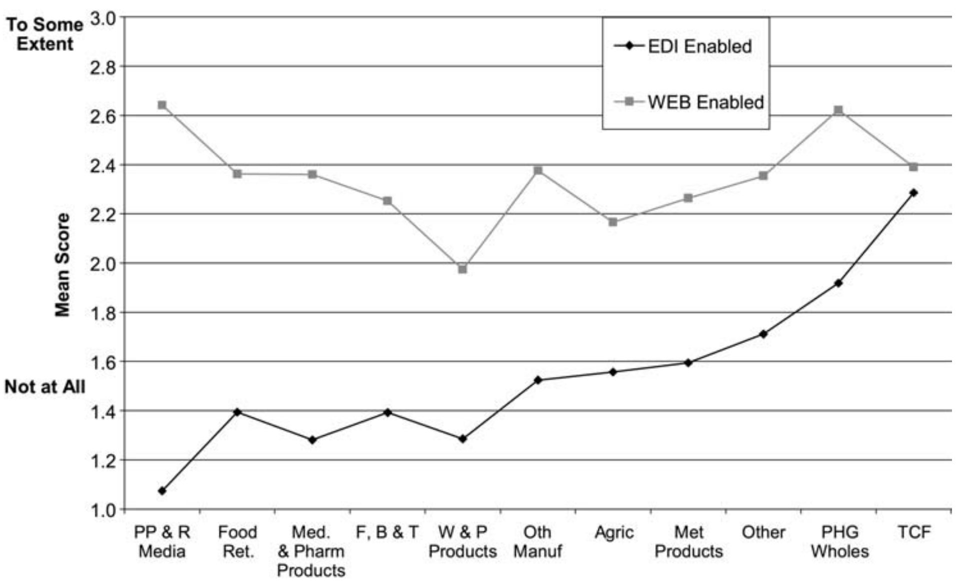


Figure 6
Does your organisation currently have an operational Web site?

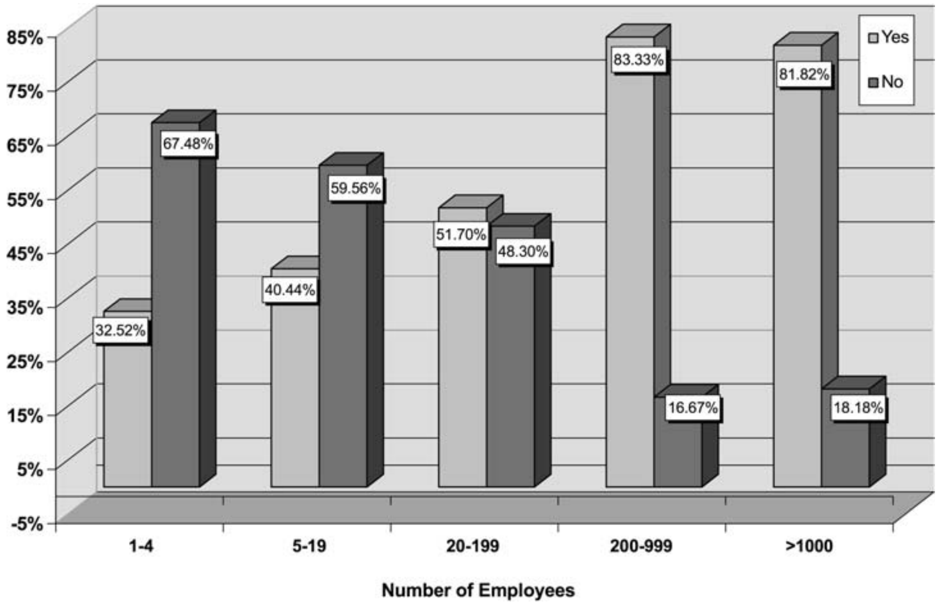


Table X
Responses to plans to implement Web sites by company size

Does your organization plan to implement a Web site?	1-4 (%)	5-19 (%)	20-199 (%)	> 200 (%)
< 12 months	42	47	55	57
1-2 years	7	12	10	14
Some time	35	28	24	14
Never	17	13	12	14

Internet-based supply chain management technologies is lower, and this may, in part, account for the comparatively rapid rate of adoption.

For the practitioner these results point to the Internet providing a cheaper and more easily accessible means of connecting to, and transacting with, trading partners. It would, however, be dangerous to draw the conclusion that this will mean that supply

Figure 7
Comparison between current and planned Web sites by ANZSIC code

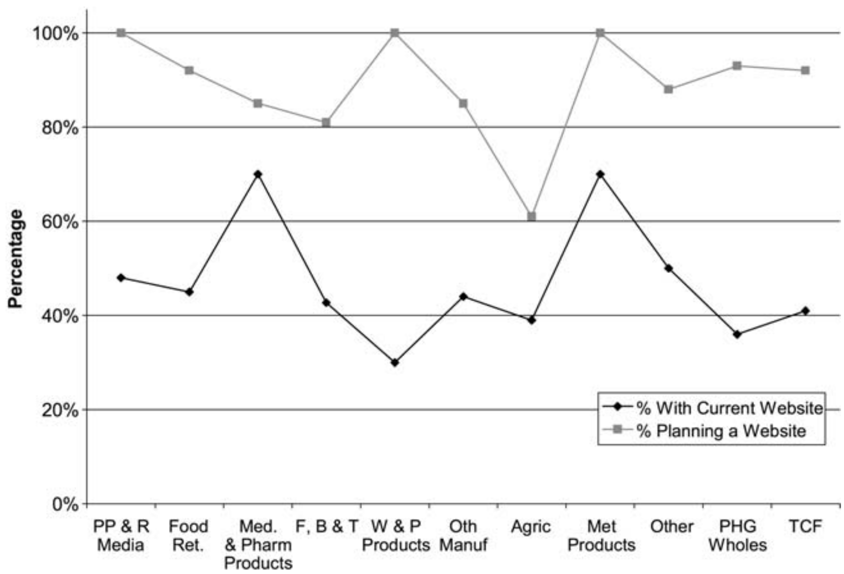


Figure 8
Comparative functions of current Web site by industry type

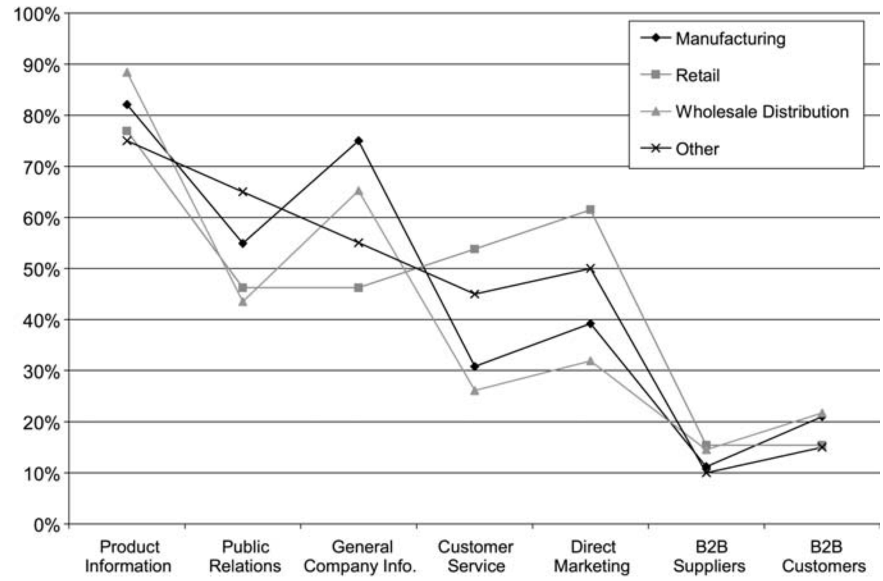
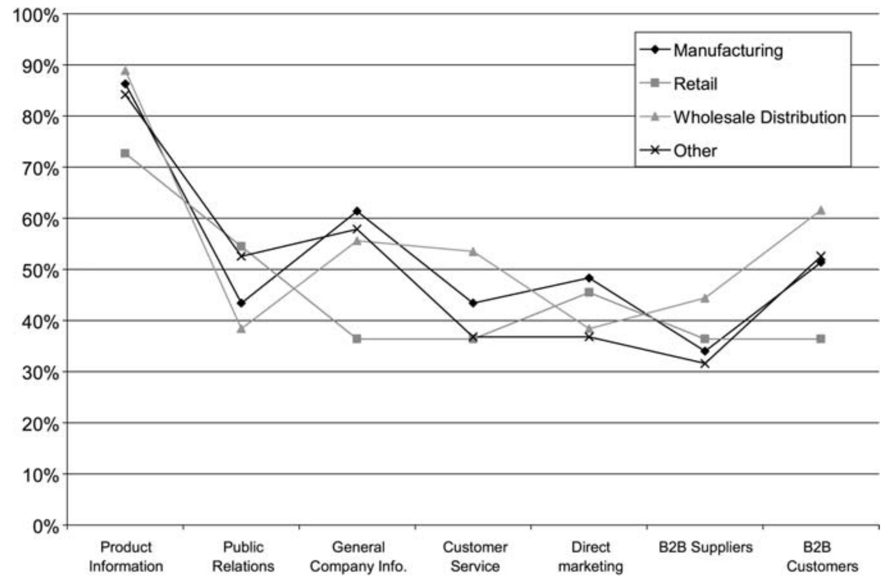


Figure 9
Comparative functions of planned Web site by industry type



chains will become more efficient and effective as a consequence. The ease of adoption of a technology does not guarantee that it will be used effectively in all cases. There is also the issue of whether the stated intentions of respondents to adopt Internet technologies reflect any real understanding of what the implications are for trading partners operating in a highly connected environment. It may be one thing for companies to say that they are going to use the Internet to facilitate trade with customers and suppliers, but do they really understand what this means? The answers will emerge over time, but there is nonetheless a clear trend toward the adoption of the Internet as a means of facilitating improved management of supply chains.

As information technologies develop, use and application of these technologies can be expected to change rapidly. The ability of organizations to connect to each other, and transact business, using electronic media, is expected to become a more simple and seamless process. The traditional barriers to entry to the world of electronic trading are being lowered by the adoption of open standards, the use of bridging technologies, and the non-proprietary nature of the Internet. At the same time, however, it can be expected that adoption and use will neither be universal nor homogeneous across all organizations. An important focal point for research in the next couple of years will be to identify and track trends in usage of the Internet (and subsequent emerging technologies) for enabling more efficient and effective B2B transactions within supply chains. Will the use of the Internet be seen to be of strategic importance, or merely peripheral, in providing a source of competitive advantage? Will usage and adoption patterns be significantly different across different types of organizations (e.g. large versus small, manufacturers versus service industries, not for profit versus for profit, etc.)? Will security concerns have a moderating effect on the rate and focus of adoption and use in some organizations? Will there be industries that will be restricted in their ability to extract value from the use of these technologies due to structural and cultural factors? How will usage patterns change over time, and what will be the implications of trends in usage patterns for all players? With developments in this area being so rapid, and with the expectations for radical change and improvement in operations being so high, it would be extremely useful to be able to monitor and document how, where and why the technology is being used. By extension, it may be possible to propose how it may be used more effectively.

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XML-based supply chain integration: a case study

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Supply chain, Integration, Computer languages, Evaluation

Abstract
This paper describes experiences gained from the implementation and evaluation of an XML-based integration system in a real case. The prototype was designed to support electronic data exchange in a supply chain. The purpose of the prototype was to study the properties of the integration system from both a development and usage perspective. In particular, the study outlined how and in which circumstances XML facilitates supply chain integration. EDI provided a point of comparison. This information is useful both for the developers and users of integration systems.

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Introduction

Since the mid-1990s Internet-related technologies have created increasing technical opportunities for communication between different companies (Shim *et al.*, 2000). Also, many manufacturing companies have changed their operations into forms of co-operation that can benefit from increased communication opportunities. These two parallel developments provide the motivation for studying an alignment between them.

The main objective of this study is to examine to what extent XML-based integration systems can support supply chain integration between companies. The integration systems represent an applied type of Internet technologies that is becoming popular. Java and XML form a basic type of these technologies that is already in favour. In this paper, a prototype of the integration system called the Communication Application (CA) is used as a test bed for evaluating the benefits and costs of XML-based integration systems compared to EDI. The study also comprises experiments with some implementation approaches to the prototype. In particular, the configuration that is done solely with XML is divided into layers and its functionality can be updated dynamically. The prototype has been implemented using Java. These features should facilitate the maintenance of the prototype.

The prototype has been studied with a real case, in which the main contractor of the production network is a switchgear production company, ABB Control. The other companies in the network are subcontractors and suppliers of the main contractor. This network is to a large extent a traditional production network, but very large orders that exceed the main contractor's capacity require increased co-operation with the subcontractors. This co-operation has to some extent different characteristics from ordinary purchasing. The prototype has been developed for and experimented with in this case. One of the subcontractors, InCap Electronics, was involved in these experiments.

This paper is structured in the following way. Background information on XML-based supply chain integration is presented. This section includes a brief introduction to supply chain management literature, the requirements in the case, and the XML-technologies used in the implementation of the prototype. The structure and configuration of the CA (GNOSIS-VF, 2001a, b) is presented. The methods and results of the evaluation of the CA in the case (GNOSIS-VF, 2001c) are summarised. Finally, the conclusions are presented.

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Background

Supply chain management

A supply chain means a flow of goods and services through different sites. Information also plays an important role in these flows. Supply chain management encompasses logistics that studies material and information flows, purchasing, and selling in terms of operative questions, such as transportation, ordering and packing, as well as strategic questions, such as competition. Although there are a large number of definitions for supply chain management, it is a more comprehensive concept than logistics. Supply chain management deals with material and information flows from raw-material production to final product retailing.

The SCOR-model (Supply Chain Council, 2002) provides a description of processes in the supply chain. It consists of the following processes:

1 *Plan*: demand/supply planning.
2 *Source*: sourcing/material acquisition, manage sourcing infrastructure.
3 *Make*: production execution, manage make infrastructure.
4 *Delivery*: order management, warehouse management, transportation and installation management, manage deliver infrastructure.

This model requires integration of participants in the supply chain. These participants are not just different sites within the same company but they often belong to different companies. The latter case is in many ways much more difficult than the former one. In all, supply chain management is about integration.

Requirements

ABB Control has a switchgear factory located in Vaasa, Finland. ABB Control is part of the world-wide ABB group and it produces switchgear assemblies for both internal and external use. The case is based on the idea that the functionality of an in-house information system can be expanded to support supply chain integration. The geared functionality of the integration system will cover the functionality that is related to production management and purchasing with respect to internal and external resources.

ABB Control's business process model related to the execution of customer orders is quite traditional. Generally, ABB Control uses internal resources to carry out production, but in production overload situations it has to use external resources, which may be either other ABB companies or local subcontractors. The combination of internal and external production resources forms a supply chain. The basic idea behind such co-operation is the flexible transparency of internal and external production resources. Production management has the possibility of planning external resources as internal ones. The expected business benefits from supply chain integration are related to improved production flexibility and more profitable data exchange. Figure 1 illustrates a co-operation model in which a subcontractor produces ABB-specific products, whereas a supplier does not.

The co-operation model of supply chain integration can mainly be implemented with current software technologies. A number of commercial integration systems (see e.g. Microsoft, 2002) are available. However, taking into account the unstable status of the new technologies, the case gives an opportunity to design and implement a prototype of the integration system. The objective is to achieve the prototype that can be easily maintained and used, and to utilise XML-technologies. The purpose is for XML to be used to extend supply chain integration to those subcontractors who have not accepted EDI. The architecture of the prototype is based on the following model. A central part of this architecture is a server that supports EDI, XML, or both. Clients of this server can be browsers, other integration systems, or applications. This is not the only possible model but many commercial integration systems at least partially conform to this architecture. The implementation of supply chain integration requires the design of the required semantic message models and their interaction-handling logic. The content of the messages can be based on XML-based e-business frameworks (BizTalk, 2002; ebXML, 2002; RosettaNet, 2002; xCBL, 2002).

A large number of potentially useful interactions are identified in the context of supply chain integration (GNOSIS-VF, 2001d). In this case, the objective is for the prototype to be capable of performing the following interactions:

- ABB sends a specific purchase order to a specific subcontractor. Query the database for an order, translate the order from the EDI segments to the xCBL format, send this order as an e-mail or a message to a subcontractor, and return success/failure.
- A subcontractor queries for one of its purchase orders. Query the database for an order, translate the order from the EDI segments to the xCBL format, and return the order.
- A subcontractor queries for a list of all its purchase orders. Query the database for orders, translate the orders from the EDI segments to the XML format, and return a list.
- A subcontractor updates a purchase order response into a database of ABB. Translate an order response in the xCBL format to INSERT statements for EDI segments, update the database, and return success/failure.
- A subcontractor updates an invoice into a database of ABB. Translate an invoice in the xCBL format to INSERT statements for EDI segments, update the database, and return success/failure.
- A subcontractor queries for a demand forecast of its possibly forthcoming purchase orders. Query for forthcoming orders, translate the forthcoming orders from the EDI segments to the XML format, and return a demand forecast.

All these interactions, except the last one, are used as a starting point in the design and implementation of the prototype. They were suggested by ABB Control. The final interaction is applied after implementation to evaluate the maintainability of the prototype. It was identified after implementation and suggested by InCap Electronics. xCBL (version 2.0) is utilised in the case because it provides XML-based business documents for the chosen interactions and is interoperable with EDI. XSLT is needed to make the necessary transformations between XML and EDI formats.

XML-technologies

XML

The Extensible Markup Language (W3C, 2002a) is designed to improve the functionality of the Internet by providing flexible information structuring. XML is extensible because it is not a fixed format like HTML but a metalanguage for describing other languages. XML can be utilised to design customised mark-up languages for different types of documents. XML is a subset of SGML, with some exceptions. SGML is a standard for defining descriptions of the structure of an electronic document. SGML is very powerful but complex, whereas XML is a lightweight version of SGML that removes all the features making SGML too complex for the Internet.

The XML standard defines the syntax of a mark-up language that is applied to represent the structure of an electronic document. These documents are composed of a set of objects that may contain elements. Each element may have a number of attributes, according to which the document will be processed. XML provides a formal syntax to describe the dependencies between the objects, elements and attributes, and to build an electronic document.

The XML document has to be well formed or valid. The document is well formed if each non-empty element has a start-tag and an end-tag between tags of its parent element. The document can be validated by DTD, which defines elements of the document and a hierarchical order between them. DTD also defines attributes of the elements and values of the attributes.

XSLT

The Extensible Stylesheet Language Transformations (W3C, 2002b) is a language for transforming XML documents into other XML documents. XSLT is not intended as a completely general-purpose XML-transformation language but it is designed for use as a part of XSL, which is a stylesheet language for XML. XSL includes an XML vocabulary for specifying formatting.

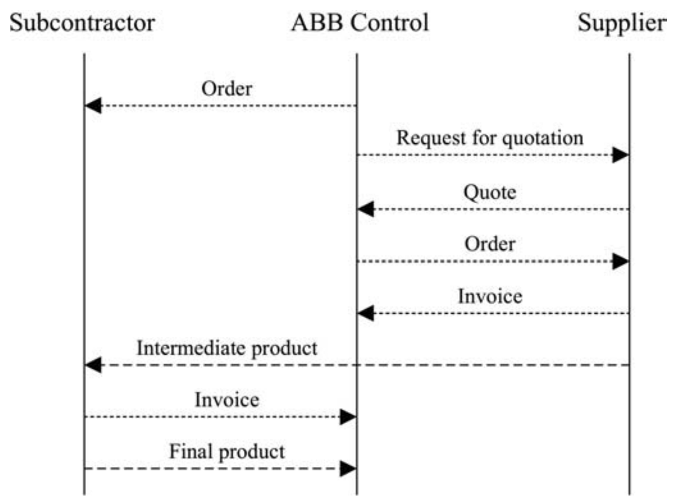
A transformation expressed in XSLT describes rules for transforming a source document into a result document. This stylesheet contains a set of template rules, which consist of patterns and templates. This allows a stylesheet to be applicable to a wide class of documents that have structures similar to the source document. A pattern is matched against elements in the source document. A template is instantiated to create part of the result document that is separate from the source document. In constructing the result, elements from the source can be filtered and reordered, and arbitrary structure can be added.

xCBL

The Common Business Library (xCBL, 2002) is a set of XML building blocks and a document framework that allows the creation of reusable XML documents for e-business. Although XML provides a self-describing document, stronger data typing and validation for e-business transactions is needed. In addition, there is a proliferation of industry-specific elements that would potentially lead to problems. xCBL is a combination of the leading XML industry initiatives and most common cross-industry XML elements. Fundamental documents, such as orders and invoices, and elements, such as country codes and currencies, have been captured in xCBL.

Since the applications are heterogeneous, integration would have to take place at a semantic level where components communicate through a common language, vocabulary, and business concepts. xCBL is not a single standard but a collection of

Figure 1
A co-operation model



common business elements that underlie all EDI and Internet protocols. xCBL has been developed after EDI semantics, such as EDIFACT. Its reusable components should speed the implementation and facilitate interoperation by providing a common semantic framework.

Implementation

Structure and functionality

Architecture

The prototype conforms to a layered software architecture that could be described as an engine-processor architecture. The motivation for this type of architecture is maintainability. The CA is integrated to other systems using standard techniques, such as HTTP, ODBC, and SMTP. Figure 2 illustrates the engine-processor architecture of the CA.

An engine, which processes the interaction requests and executes them according to the configured interaction definitions, forms the top layer of the architecture. These define the interaction-handling logic in terms of parameters and operations. The bottom layer of the architecture contains a set of processors that are able to perform the operations. The CA can load these processors and their configuration data "on demand" from the local file system or the Internet. This makes it possible to maintain the functionality of the prototype without code changes to the engine. In addition to portability, Java supports the previous kind of extendibility. The system configuration data has to reside on the same host as the system itself whereas all other configuration data can be retrieved from the Internet.

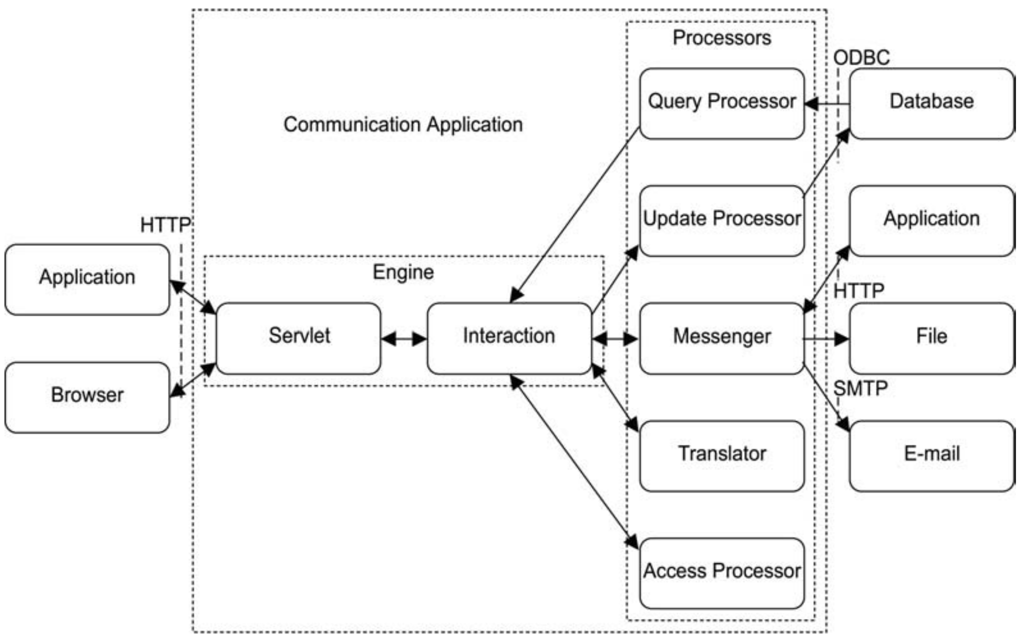
Engine

The engine of the CA processes the interaction requests according to their configuration data. The processing logic is as follows:

1. The engine processes the interaction requests from clients. The requests can be in either HTML or XML formats. A Servlet passes the call to an interaction, which is associated with the configured interaction definitions.
2. The interaction executes the requested interactions with the given parameter values and configured interaction definition as inputs. It interprets the XML-based interaction configuration language and calls the processors according to the configured definitions. When a processor has executed an operation successfully it saves the output and the interaction object passes it to another processor if necessary. When all operations of the interaction are executed the interaction returns the result.
3. The Servlet sends the result to the client as an interaction response. The response can be presented in different formats, e.g. plain text, XML, or HTML.

The engine also keeps a log on interactions executed. For each interaction request, it records information about when the request

Figure 2
Architecture of the prototype



was executed and from which address it was made. In addition, the engine records the parameter values and result of the interaction. If the interaction fails, an error message is recorded.

Processors

In the case study the CA has five processors. Since the CA is designed to be expandable, it is capable of loading and calling an object as a processor if the object implements a generic processor interface. The roles of the processors are presented in the following:

1. The query processor retrieves data from a relational database. Its inputs are values associated with the *select* statement to be executed. The output is a result of this statement translated into XML format.
2. The update processor manipulates the data content of a relational database. The input consists of *update, insert*, or *delete* statements in XML format. The processor has no output.
3. The messenger saves a document or a request to a specified target. Its inputs are a document or request to be sent and a target name. In the case of a request the messenger is left waiting for a response, which is its output. The request can be an interaction request and the target may be another integration system. In this way it is possible to delegate the processing of interactions between integration systems in the different sites.
4. The translator is an essential processor from the point of view of supply chain integration. It transforms input from one XML-based format into another. The output of the processor is a result of the XSLT translation specified as a part of the configuration.
5. The access processor checks the password given by the user. Its inputs are a user name and password. If the password is invalid, the processor aborts the execution. Otherwise, the output of the processor is the identification associated with the user that can be used by other processors.

The generic processor interface is based on methods for initialising a processor with configuration data, setting its input values, executing the processing, and getting its output value. This is important because the engine is able to interact with the processor only by these methods.

Configuration

A large part of the actual functionality of the CA is defined with XML-based configuration languages instead of lower level programming languages like Java. This is motivated by easier maintainability.

The configuration data is divided into three levels. The system level configuration data specifies which interactions are defined for the system. The interaction level configuration data defines which parameters and operations are required for the execution of an interaction. At the operation level the configuration language is specific to the processor that executes the operation.

Interaction definitions form a core of the configuration of the prototype. A balance between flexibility and simplicity has been aimed for by defining interactions as operation block models. The interaction has parameters whose values are given by the sender of the request. These parameters are inputs for operations that are sequentially executed in order of appearance. Each operation has a link to the processor that executes the operation with a given configuration and inputs. Some operations return output that works as an input for the following operations or as a result of the interaction. If an exception is detected during the execution of the interaction, it will be reported to a receiver and the execution will be aborted.

The following example shows the configuration of the CA at the system, interaction, and operation level. In this example a user from InCap Control wants to get information on a purchase order. Figure 3 shows the configuration data at the system level. An interaction is identified by an operation-content-document-triple that refers to the interaction definition. In the example it is a question of a query-xcbl-order-interaction whose definition is located in file://query-xcbl-order.xml

Figure 4 illustrates an interaction definition for querying a purchase order. The configuration data of the first operation, access, is located in file://query-xcbl-order-access.xml The program code of this operation lies in file://AccessProcessor.class If this operation is successful, the execution proceeds to the second operation, query, and so on.

At the operation level configuration data can be presented in many different ways. Although a processor may have very sophisticated needs in terms of configuration, configuration data should be represented in XML. Figure 5 gives an example of the configuration of the Access Processor.

From the viewpoint of maintainability, the hierarchical structure of the configuration data has an advantage by providing independence between the different levels.

Figure 3
An engine configuration

```
<configuration dtd="file:request.dtd" html="file:xml-to-html.xsl">
  <interaction operation="send" content="xcbl" document="order">
    file:send-xcbl-order.xml
  </interaction>
  <interaction operation="query" content="xcbl" document="order">
    file:query-xcbl-order.xml
  </interaction>
  <interaction operation="receive" content="xcbl" document="invoice">
    file:receive-xcbl-invoice.xml
  </interaction>
</configuration>
```

Figure 4
An interaction definition (query-xcbl-order.xml)

```
<interaction-definition>
  <parameter name="user" type="String"/>
  <parameter name="password" type="String"/>
  <parameter name="order-id" type="String"/>
  <operation name="access"
    processor="file:AccessProcessor.class"
    configuration="file:query-xcbl-order-access.xml">
    <input name="user"/>
    <input name="password"/>
  </operation>
  <operation name="query"
    processor="file:QueryProcessor.class"
    configuration="file:query-xcbl-order-database.xml">
    <input name="order-id"/>
    <input name="access"/>
  </operation>
  <operation name="translation"
    processor="file:Translator.class"
    configuration="file:query-xcbl-order-translation.xsl">
    <input name="query"/>
  </operation>
  <result name="translation"/>
</interaction-definition>
```

Figure 5
A processor configuration (query-xcbl-order-access.xml)

```
<permission>
  <access user="abb" password="control" id="%"/>
  <access user="incap" password="electronics" id="1"/>
</permission>
```

For example, if the passwords of users are changed, there is no need to make changes at the system or interaction level. On the other hand, if the access check is removed, the configuration data remain the same at the system level.

Evaluation

Scope and methods

The main objective of the evaluation was to determine how and to what extent the CA would support supply chain integration between companies. An objective of the study was to assess the viability of the chosen approach by identifying its potential benefits and expected implementation and operating costs in a supply chain context.

The evaluation plan was originally drafted on the basis of a set of assumptions about the main benefits of XML-based integration systems, such as the CA. The main hypothesis was that they could provide a good basis for supply chain integration between companies. In particular, it was assumed that they would be more flexible to maintain, and less expensive to implement and operate than most currently used business-to-business systems, such as EDI.

On the basis of these assumptions, it was considered that SMEs, especially, would be interested in the integration system, provided that its benefits can be identified and illustrated in the correct way. In consequence, it was also considered that even larger companies might regard it as a feasible extension to their existing communication solutions when partnering with SMEs. An objective of the evaluation process was to assess the adequacy of these assumptions.

The evaluation was conducted in the form of a two-tier cost-benefit analysis. The first phase of the evaluation was a case study, whereas the second phase focused on the generalisation of the case-specific results. The very idea of the arrangement was to produce more generic information on the potential benefits and costs of the integration system concept.

The work was carried out in close co-operation with ABB Control. This provided an invaluable opportunity to test new ideas and solutions in practice and to get immediate feedback on their feasibility to the needs of ABB and InCap Electronics. Since ABB and InCap were using EDI for exchanging a part of their order and invoice data, the case also enabled a comparison between CA and EDI with regard to their support for operations and costs.

The main challenges of the evaluation were related to the identification of those factors that might add either to the cost or to the benefit side of the calculation. Finally, six groups of factors were identified as important contributors to the viability of the integration system concept and were given special emphasis in the evaluation. These key areas were as follows:

1 *Functionality and technical feasibility*. This area of the evaluation aimed at assessing the applicability of the chosen mechanism to mapping structured business documents of diverse syntax to each other. In addition, attention was paid to the functioning of implemented interactions as well as to the overall technical feasibility of the prototype.
2 *Scope of interactions*. This area was more theoretical in nature and related to the expressive power of the chosen architecture and its configuration mechanism. The objective was to determine the extent to which they could possibly cover ABB's communication needs in subcontracting and related partnering.
3 *Impact on business*. The objective was to identify the potential business benefits as well as the expected disadvantages of operating a CA type of integration system at ABB. Areas like flexibility, reliability, efficiency, speed and costs, i.e. the key attributes of any process or practice, were addressed during the evaluation.
4 *Implementation demands on the organisation*. The objective was to identify the challenges and needs for change that the implementation of a CA type of integration system might cause for ABB's processes, practices and organisation.
5 *Configuration and maintainability*. The objective was to determine the basic requirements for the definition and modification of interactions in terms of necessary know-how and work inputs. Another related objective was the specification of a feasible model and arrangements for the initial configuration process and related systems support.
6 *Use of EDI*. The objective was to examine the utilisation of EDI at ABB, to identify its main benefits and support for purchasing practices, and to construct an extensive picture of all EDI-related implementation and operating costs. The purpose of analysing the use of EDI was to establish a kind of reference point for the CA.

The evaluation methodology was largely developed as the work progressed. Important methodological references included Anandarajan and Wen (1999), Luoma *et al.* (1999), Willcocks and Lester (1999a, b), and Zuboff (1988). The main methodological challenges related to the identification and assessment of the potential benefits and costs of a system that was not operational at the time of the evaluation. In consequence, special emphasis was given to developing methods that would make it easier to identify what a corresponding operative system would be able to do if it was actually implemented and brought into production use at ABB. Therefore, not only demonstrations and experiments with the CA, but also numerous discussions and workshops with the representatives of the case companies had an important role in the evaluation process. This resulted in a rich picture of the case companies' processes and systems, and the potential role of a CA type of integration system in that domain. Different types of models, such as ABB's order-delivery process models and interaction diagrams to describe functionality of the CA, were used to facilitate discussions and analysis.

For the most part, the evaluation results were based on consensus. For example, the results of functional tests were jointly investigated because the work required a profound understanding of EDI and xCBL. Estimates on the expected implementation demands and potential business impacts were mainly grounded on the views of the case companies. Configuration and maintenance-related demands and costs were estimated by the developers of the CA on the basis of their own experience from the development process. Estimates on the EDI-related benefits and costs were provided by ABB's system specialists with extensive EDI development experience.

The inherent uncertainly of the topic and the importance of case-specific information favoured the chosen arrangements. In addition, alternative options were few since only ABB and its subcontractors were able to provide the information that was needed. Respondent bias did not prove to be a problem in this case because neither the representatives of the case companies were responsible for implementing the prototype, nor were they committed to bringing it into production use. Therefore, given estimations were based on the best available knowledge and experience.

Results

Functionality and business benefits

The implementation process of the CA appeared to be flexible due to the fact that interaction definitions are stored in text files that can be created and maintained by means of ordinary text editors. Functional tests of implemented interactions were completed successfully, including those that were run over the Internet. However, with regard to purchase order, purchase order response and invoice, the content checks revealed some disparities between the corresponding business documents in xCBL and EDI formats. Identified deviations mostly related to differences between the two formats, which actually made a perfect match impossible. Such problems can usually be resolved because data structures can be flexibly added to or removed from XML-based business documents.

The chosen engine-processor architecture, together with its XML-based configuration mechanism, proved to function well and to form a good basis for further development of XML-based integration systems. For example, all interactions that were identified as "potentially useful" by ABB were either implemented or could have been implemented in the CA. Some of those interaction types were not supported by the EDIFACT, and only a few of them were actually used in Finland. Therefore, the test case would support the feasibility of the chosen architecture and configuration mechanism as an implementation approach to the integration system.

The test case suggests that the business benefits of integration systems in general are highly dependent on the scope of their implementation and on case-specific needs. In the case of ABB, they mostly related to production planning and supervision, and the functioning of the customer interface. In consequence, ABB was especially interested in the possibility of exchanging subcontractor capacity and order processing status-related information. Assessed benefits related to enhanced information management, more efficient use of available production resources and, consequently, shorter lead times. InCap emphasised the importance of demand forecasts as a medium in its production planning practice. With regard to purchase orders, purchase order responses and invoices, the expected benefits were similar to those of EDI: higher efficiency of administrative routines.

Demands and costs of implementation and operation

When assessing the potential starting-points for implementing the CA, two different scenarios were identified: establishing a new electronic connection between ABB and one of its subcontractors, or replacing an existing EDI connection. The general conclusion was that in both cases the implementation demands on an organisation would be very similar to those of any other information system, i.e. involving extensive negotiations and co-operation with the two partners as well as a great deal of specification and testing. However, some special characteristics were identified.

The first relates to the utilisation of the Internet instead of tailor-made connections. As a result, there would be no mediator between the two organisations which, in turn would probably result in significant savings in communication charges. On the other hand, in such a situation it is up to the end-user organisations to establish proper arrangements for managing the connection, e.g. ensuring data security and eliminating duplicate messages. Usually the EDI operator provides this service. It is not yet clear what would be the most feasible future solution to this particular challenge and how much it might cost.

Another special characteristic concerns the case when the subcontractor decides to operate the system through a browser instead of an integration system of its own. In such a case the subcontractor's implementation process would be relatively straightforward. However, from the main contractor's point of view, this scenario involves several uncertainties. For example, the number of erroneous messages is likely to increase in the case of a growing number of manual working stages involving direct database operations. Such errors are likely to end up in operative information systems, thus causing excess administrative work. There is no obvious solution to this challenge although proper training is certainly a key issue here. However, it can be reckoned that the main contractor would have to invest more time and resources in supervising the use of the system.

The configuration of the CA requires a lot of background information. Getting that information requires work and takes time. In the test case, the total amount of time needed for defining one interaction was reported to range from a couple of hours up to a couple of weeks. The large variation mostly relates to the complexity of XSLT translations determined by the characteristics of the data structures to be mapped to each other. It was estimated that on average the definition of an interaction takes around one week's work. This is based on the developers' estimate, provided that the work is done by an external IT expert with a good knowledge of XML, XSLT, and xCBL, with a profound understanding of the integration system, and with no previous knowledge of the company information system to which the integration system is to be connected. These conditions applied to the developers of the CA. In addition, the data contents have to be specified in advance, as they were in the test case apart from one interaction. If the configuration process involves business planning, for example, negotiations between several partners on the content of messages, much more time will be needed.

In the course of time, there were learning effects. For example, modifications to the existing interactions were effected swiftly. Existing interaction definitions also formed a good basis for the definition of new ones of a similar type.

Comparing the costs of EDI and CA

The implementation costs of EDI were assessed to be clearly higher than costs of the CA. With regard to the amount of necessary work alone, the introduction of a new message type, which corresponds to the definition of a new interaction in the CA, was found to require a new EDI module and about 200 hours' work of related specification and testing. Opening a new connection, i.e. taking a particular message type in use between two partners, was found to require a couple of days of testing. Provided that the testing times are about the same with regard to EDI and CA, it can be assumed that establishing an EDI connection for a new message type is at least three to four times more expensive than implementing a new interaction in the CA.

Finnish software firms have shown interest in further development of the CA. They have not been able to give any estimate of the order of the future market price (licence fees) for a CA type of commercial integration system. When charges for use are taken into account, the XML-based integration system seems certainly less expensive, because it is based on the use of the Internet. However, it is difficult to forecast whether the application service provider concept will also make progress in this field. Should this happen, the charges for communicating through an XML-based integration system may be commensurate with those of EDI, especially if related services are provided by EDI operators.

Conclusions

This paper has presented a prototype of the XML-based integration system implemented and tested at ABB Control and InCap Electronics. The main conclusion is that the prototype provides a sound basis for XML-based supply chain integration. Since XML enables customised business documents, which can be transformed using XSLT, and integration systems are based on the Internet instead of tailor-made connections, the prototype is more flexible to implement and operate than EDI. In addition, the engine-processor architecture, together with its XML-based configuration mechanism, facilitates the maintenance of the prototype.

At this point, only preliminary results concerning the industrial use of the approach exist. The results show that within the test case the prototype can fulfil the functional requirements of supply chain integration. Business benefits of the prototype are highly case-specific but its use provides significant cost savings in comparison to EDI. However, it is not completely clear to what extent these savings are attributable to the properties of the prototype or to other contributing factors, e.g. different cost structures of EDI operators.

XML-based integration systems have the potential to reduce entry barriers into e-business. Integration systems have lower implementation costs than EDI. A subcontractor needs no integration system of its own if it can use the main contractor's integration system by a browser. For SMEs requiring less frequent data exchange, these are important factors. Operating costs are also lower for integration systems, but this is not necessarily permanent. Generally, the flexibility of integration systems is to their advantage but without shared understanding of business documents it may turn out to be to their disadvantage. Therefore, XML-based e-business frameworks, such as xCBL, play an important role in XML-based supply chain integration. Although changes in XML-technologies have slowed down in adoption in supply chain integration, XML-based integration systems provide a significant alternative to EDI.

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Collaborative supply chain planning using electronic marketplaces

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Supply-chain management, Production planning, Internet, Business development, Business-to-business marketing

Abstract
The purpose of this paper is to show how the functionality of electronic marketplaces can facilitate collaborative supply chain planning. Supply chain planning processes are identified and analysed using a supply chain management focus. The paper also gives a brief introduction to a framework for supply chain management and to the typical structure of electronic marketplaces. Furthermore, three collaborative supply chain planning scenarios are defined, and it is shown how collaborative supply chain planning typically could be implemented on an electronic marketplace by the means of a Web-based demonstration. As such, the paper shows how electronic marketplaces can be used to enable supply chain integration.

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Introduction

The globalisation of markets and manufacturing has forced the management of supply chains to not only consider business processes in the traditional value chain, but rather processes that penetrate networks of organisations. Hence, the research on supply chain management has turned from an intra-enterprise focus towards an inter-enterprise focus. In this network setting the so-called bullwhip effect (see e.g. Forrester, 1961; van Ackere *et al.*, 1993) has gained increased interest. Creating information visibility and capturing the moments of information enable collaborative members of the supply chain to manage their business processes better (Lummus and Vokkurka, 1999). Yet, this puts high requirements on the management of information. Paper-based systems for managing information flows are very slow, prone to error, and difficult to update. Therefore, many companies experience a need to seek more efficient ways to share information between supply chain members (Wenninger, 2000). Consequently, there has been a growing interest in electronic business (e-business) solutions to facilitate information sharing between organisations in the supply chain.

Electronic commerce (e-commerce), which is the aspect of e-business that has garnered most attention, is often defined as the buying and selling of goods and services on the Internet, especially the World Wide Web. It includes business-to-business (B2B) and business-to-consumer (B2C) buying and selling, electronic data interchange (EDI), online catalogues, etc. E-business is in turn defined as conducting business on the Internet. In this sense, e-business is not just buying and selling, but also servicing customers and collaborating with business partners. IBM (2001) regards e-business as "the use of Internet technologies to improve and transform key business processes". It is in this context that electronic marketplaces are regarded as one important part of e-business solutions in the process of enabling supply chain integration.

An electronic marketplace can be described as a virtual marketplace on the Internet, where companies can gather and conduct business with each other. The initial services on electronic marketplaces have often only included simple buying and selling solutions for indirect materials, i.e. e-commerce. As technology has progressed, the demand for additional services has increased. Thus, requirements have been put on software providers to develop new services, i.e. e-business solutions. By integrating collaborative supply chain services through an electronic marketplace, companies can collaborate and share information with each other, without having to implement expensive EDI networks. An electronic marketplace can thus be a facilitator for seamless information sharing and create visibility in the supply chain. However, to be efficient the electronic marketplace must have predefined settings and easy access for the supply chain members.

The overall purpose of this paper is to show how the functionality of an electronic marketplace can facilitate collaborative supply chain planning. More specifically, collaborative business processes are identified and analysed with a supply chain management focus. In the following, a brief introduction to supply chain management and electronic marketplaces are presented. Thereafter, the paper focuses on supply chain planning, investigating collaborative activities and identifying typical collaborative processes. Based on this, three collaborative business scenarios are defined with examples of how these scenarios can be implemented on an electronic marketplace

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using SAP software. Finally, some concluding remarks and ideas for future research are presented.

Supply chain management

There are almost as many definitions of what constitutes a supply chain and supply chain management (SCM) as there are people writing about it. Recently, the globalisation of manufacturing has forced the research on manufacturing and logistics to not only consider material flows in the traditional value chain, but rather in a network of facilities. First of all, it is important to include the customer perspective in a supply chain definition. Second, most companies today try to work with processes and not functions. Third, a collaborative environment is starting to grow and it is better to study organisations than linked facilities. A relatively "old" definition encompasses all these issues and will be the definition used throughout this paper. A supply chain is:

> ... the network of organisations that are involved, through upstream or downstream linkages, in the different processes and activities that produce value in form of products and services in the hand of the ultimate consumer (Christopher, 1992, p. 12).

Turning to the management of the supply chain, the Global Supply Chain Forum (formerly The International Centre for Competitive Excellence) provides a definition of SCM that follows logically from Christopher's definition of a supply chain:

> Supply chain management is the integration of key business processes from end user through original suppliers that provides products, services and information that add value for the customer and other stakeholders (Lambert *et al.*, 1998, p. 1).

A group of researchers (Cooper *et al.*, 1997; Lambert *et al.*, 1998) has developed a framework for SCM. The framework consists of three major elements and is in congruence with the definitions of a supply chain and SCM presented above.

The supply chain network structure concerns the configuration of the network of members in the supply chain and the links between them. The supply chain business processes determine those processes and activities that produce a specific output of value to the customer. Finally, the SCM components are components by which the business processes, and thus the supply chain as a whole, are integrated and managed. The methodology applied when using the framework is to first determine who the key supply chain members are. After this is carried out, it is time to identify which processes should be linked with each of these key supply chain members. Third, it is time to decide what level of integration and management that should be applied for each process link. Note that the steps are not necessarily carried out in a strict chronological order; most likely the methodology will be iterative. This research focuses on supply chain planning issues. Therefore, the whole concept of SCM as described above will not be covered. A certain group of supply chain processes will be identified. Then, electronic marketplaces will be used as a management component to integrate and manage the supply chain.

Turning to the software side of SCM, AMR Research, Inc. (AMR, 2000a, b) divides SCM into two parts:

1 supply chain planning (SCP); and
2 supply chain execution (SCE).

The major distinction between the two areas is the planning horizon, the former being more strategic and tactical, whereas the latter being more tactical and operational as shown in Figure 1. Furthermore, SCP focuses on getting ready for a job, while SCE focus on getting a job done.

This research is more focused on strategic and tactical issues, than on operational. Hence, in the following, SCP will be the object of the analysis. SCE is not within the scope of this paper.

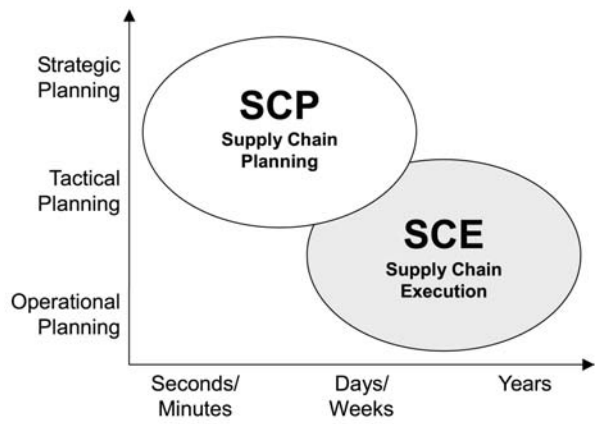
Electronic marketplaces

An electronic marketplace, or a trading exchange, can be described as a virtual marketplace on the Internet, where companies can gather and conduct business with each other. By integrating supply chain services on an electronic marketplace, companies can collaborate and share information with each other, and thus change the traditional B2B exchange of goods and services between companies. Actual demand and supply must be communicated timely and accurately back and forth through the supply chain, otherwise there is a risk of amplification of demand variances, normally referred to as bullwhip effect (see e.g. Forrester, 1961; van Ackere *et al.*, 1993). The bullwhip effect describes the phenomenon when small variations in demand from customers result in increasingly larger variations as demand is transmitted upstream along a supply chain.

Since research on electronic marketplaces is relatively new, no precise definition of what constitutes an electronic marketplace exists. However, some scholars and analyst groups have described the typical structure of electronic marketplaces; see Knight (1999), AMR (2000c), Crimson Consulting Group (2000), and Kaplan and Sawhney (2000). In the following sections some major points to explain the structure of electronic marketplaces are presented. This presentation takes a starting point in the Crimson Consulting Group's (2000) classification of electronic marketplaces along four dimensions as shown in Figure 2: industry focus, type of product, type of transaction and ownership structure.

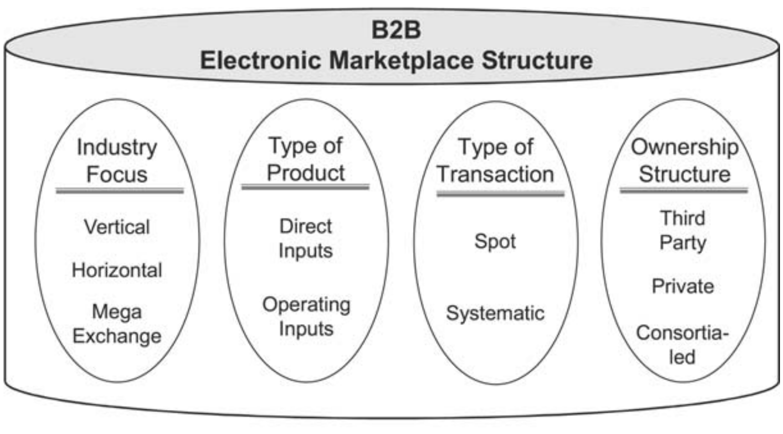
The industry focus is normally regarded from either a vertical, or a horizontal perspective. A vertical exchange serves a certain industry segment; for example, the electronics or automotive industry, whereas horizontal exchanges span across various industries and focus on functional issues, goods, and services as shown in Figure 3. Some electronic marketplaces combine a vertical and a horizontal focus to cover for certain segments of Figure 3, here referred to as mega exchanges.

Figure 1
Distinction between SCP and SCE



Source: Based on AMR (2000b)

Figure 2
Structuring electronic marketplaces in B2B environments into four typical dimensions



Source: Based on Crimson Consulting Group (2000); Knight (1999); AMR (2000c); Kaplan and Sawhney (2000)

The driving forces behind horizontal exchanges are cost reduction and standardization (Kuglin and Rosenbaum, 2000). They mainly concentrate on operating inputs, i.e. goods that are not used as direct manufacturing inputs such as office supplies, MROs (maintenance, repair and operating supplies), machinery and capital equipment, logistics services, etc. The key differentiator of a vertical marketplace is its capability to handle direct inputs, i.e. raw materials and components that go directly into a product or a process (Kaplan and Sawhney, 2000). Companies joining vertical e-marketplaces normally seek to improve competitive advantages; for example, from collaboration that enables companies to respond to uncertain market dynamics and reach economies of scale (Deloitte, 2000).

Two transaction types exist on electronic marketplaces: spot or systematic transactions. The spot transactions fulfil short-term needs of direct or operational inputs for goods and services. The typical transactions that occur in spot transactions are auctioning or other dynamic pricing models. Spot transactions rarely involve long-term relationships between buyers and sellers. Systematic transactions, on the other hand, occur in exchanges where prices are fixed or pre-negotiated and the relationships between the buyers and sellers are close and stable.

Finally, the ownership structure of electronic marketplaces can be divided into third party, private or consortia-led exchanges. The former is owned by a third party, e.g. an independent owner or a software vendor. Private exchanges are owned and managed by one or a few powerful companies within the supply chain. Consortia-led exchanges are normally made up of joint ventures between the exchange participants and the technology platform providers.

In this study, there is a major focus on vertical marketplaces dealing with systematic transactions of direct inputs. There is also a focus on private marketplaces, although the results would not be any different for the other types of ownership structure.

Collaborative supply chain planning

With the SCM framework and the features of electronic marketplaces as a background, it is pertinent to explore how the functionality of electronic marketplaces can facilitate collaborative supply chain planning. In doing this, supply chain business processes are identified and analysed, where collaboration can be enhanced by using electronic marketplaces. A business process focus is used. A sound starting point is Davenport's (1993, p. 5) definition of a business process as a:

> ... structured and measured set of activities designed to produce a specific output for a particular customer or market.

Lambert *et al.* (1998) follow this definition when they describe seven typical processes they find realistic to integrate throughout the supply chain. However, these seven processes are rather general in nature and do not specify which activities are included in each process. For the purposes of this paper, processes are depicted at a more detailed level.

Supply chain business processes

As mentioned above, the processes suggested by Lambert *et al.* (1998) are regarded too general for our purposes. Instead we use the supply chain processes identified by VICS (2000a), Hoque (2000), Norris *et al.* (2000) and Kalakota and Robinson (1999), as shown in Table I.

However, scholars tend to describe aspects of SCM in very different ways, wherefore there is a need to structure and classify the processes to get a better understanding of how electronic marketplaces can be used to facilitate the collaborative planning processes. The Supply Chain Council has developed the Supply Chain Operation Reference (SCOR) model to describe supply chain processes schematically (SCC, 2000). Processes are divided into five major process building blocks; namely, Plan, Source, Make, Deliver and Return, as shown in Figure 4.

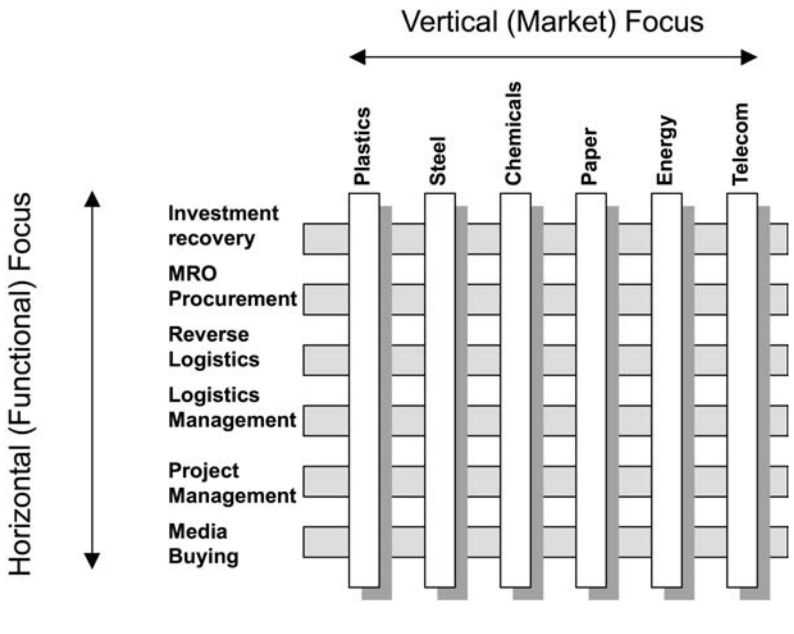
Originally the Plan process was regarded as an intra-firm activity, but in recent versions of the model Plan is regarded to be an inter-firm activity and thus with a collaborative nature. Still, a lot of planning activities take place within companies, wherefore there is a need to differ between intra-firm planning and inter-firm collaborative planning (see Figure 4).

The definition of the typical supply chain process blocks within the SCOR-model is straightforward and comprehensive, therefore that structure will be used to classify and categorize the identified supply chain processes (see Table I). Hence, processes presented in Table I can be classified as Plan, Source, Make, or Deliver processes depending on their characteristics. This is done in Table II. Note that the Return process block is not yet thoroughly defined and is therefore not used in the mapping of processes.

Since this paper focuses on supply chain issues on a strategic and tactical level and especially collaborative planning processes, the Source, Make, and Deliver blocks will be left for future research. Instead, this paper focuses on the processes within the Plan block.

Planning on an inter-enterprise basis, rather than just intra-enterprise, requires the planning to be done jointly among many of the chain's trading partners, where suppliers' and customers' constraints are incorporated within the planning process. In this way, each planning entity is responsible for developing plans for its own operations, but each plan incorporates relevant information, such as resource constraints, from other organisations. Thus, no single organisation needs to have the authority to develop plans for the whole supply chain, but a harmonised set of synchronised and relatively consistent plans can be developed through collaboration.

Figure 3
Possible vertical or horizontal focuses on electronic marketplaces



Source: Ketteman (2000)

Collaborative supply chain planning processes

Some of the activities within the processes in Table II overlap and incorporate complementary descriptions of similar activities. Therefore, these activities have been merged to find typical collaborative SCP processes. In summary, five collaborative processes have been identified (see Figure 5):

1 demand planning;
2 supply planning;
3 promotion planning;
4 transportation planning; and
5 product development.

However, all planning should be followed up in order to learn from mistakes and experiences. The supply chain will benefit from continuous monitoring of performance metrics in order to improve the processes and to ensure that every node in the supply chain carries out its tasks in a satisfying way. Therefore, there was a need to introduce a sixth process: collaborative performance management (see Figure 5). Examining performance metrics was regarded as crucial in collaborative settings to get feedback on performance from both individual members and the supply chain as a whole. The six collaborative SCP processes are described below.

Collaborative demand planning

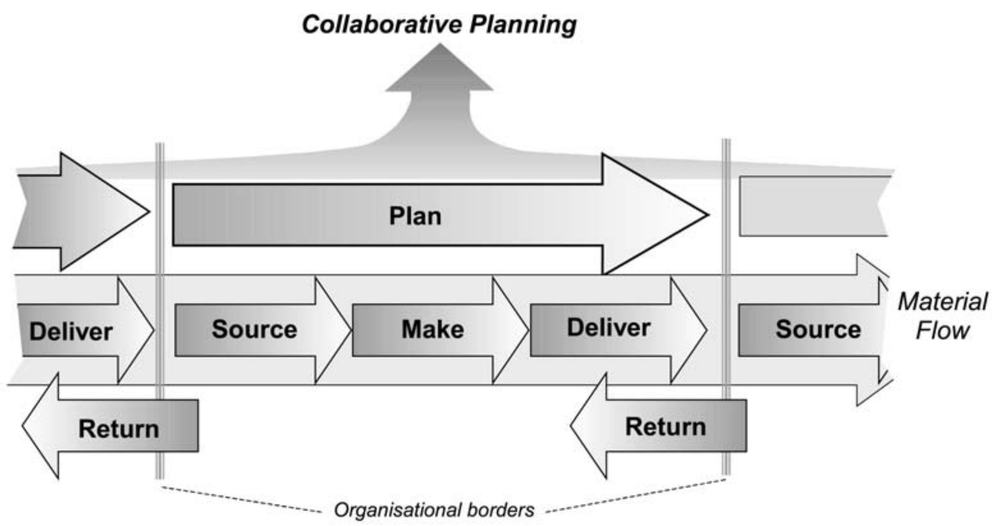
One of the reasons why demand amplification may occur is because of poorly managed demand forecasting (Lee *et al.*, 1997). By collaborating with supply chain members to establish a joint forecast, uncertainty on demand within the supply chain is reduced. This implies that it is possible to reduce some

Table I
Supply chain business processes identified in our study

VICS (2000a)	Norris *et al.* (2000)	Hoque (2000)	Kalakota and Robinson (1999)
Auction/reverse auction	Supply chain replenishment	Demand planning	Order commitment
Request for quotation (RFQ)	e-procurement	Supply planning	Advanced scheduling
Request for proposal (RFP)	Collaborative planning	Logistics	Demand planning
Purchase order release	Collaborative product development	Production planning/ fulfilment	Transportation planning
Collaborative planning, forecast and replenishment (CPFR)	e-logistics		Distribution planning
Vendor managed inventory (VMI)			Order planning
Transportation and shipment tracking			Replenishment
Demand forecasting			Production planning
Promotion management			Distribution
Buyer and seller aggregation			

Note: For detailed descriptions of the processes, please refer to each respective reference

Figure 4
The SCOR model is organised into five major management processes



Source: SCC (2000)

of the inventory, especially the safety stock, due to more accurate demand information. Both demand planning and demand forecasting aim to predict demand patterns for goods and services. The activities from these processes have been merged into one, collaborative demand planning, which also can be combined with features from CPFR (VICS, 2000a).

First and foremost, the collaborative demand planning process should be integrated with the primary supply chain members (Lambert *et al.*, 1998), in order to evolve the managed process links within the chain. Collaborative demand planning is, furthermore, most suitable for systematic transactions of direct inputs (Crimson Consulting Group, 2000), since the relationships are more stable in these settings. Therefore, collaborative demand planning is considered to be more appropriate on a vertical marketplace, where direct inputs are the most common transaction. Yet, the ownership of the marketplace should not influence whether or not collaborative demand planning is possible to integrate using electronic marketplaces.

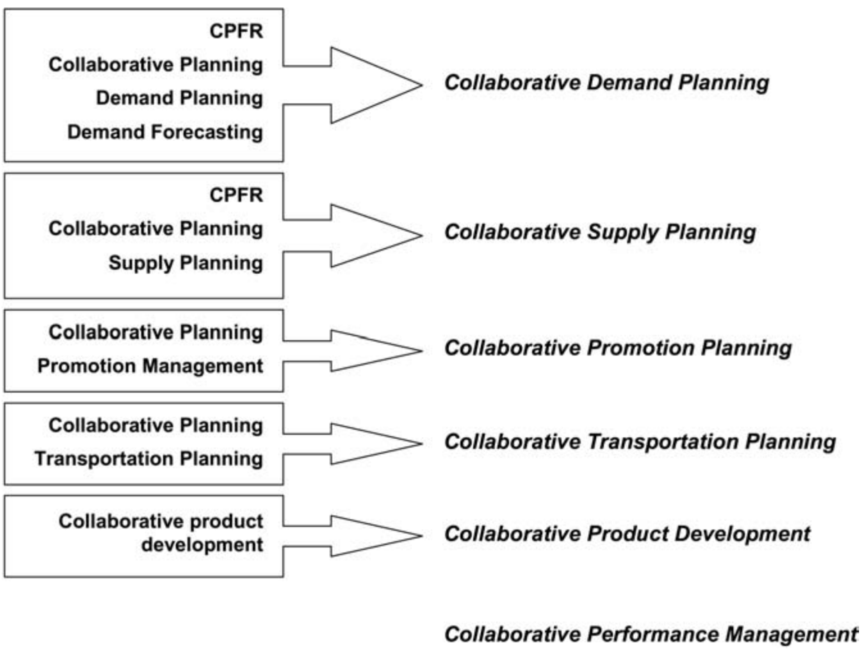
Table II
Supply chain processes (see Table I) categorised with the SCOR model as references

Plan	Source	Make	Deliver
CPFR	Auction/reverse auction	Production planning/ fulfilment	VMI
Collaborative planning	Buyer and seller aggregation	Order commitment	Replenishment
Demand planning	e-procurement	Order planning	e-logistics
Demand forecasting	RFQ	Advanced scheduling	Logistics
Supply planning	RFP	Production process	Distribution
Transportation planning	Purchase order release		Transportation and shipment tracking
Promotion management			
Collaborative product development			

Note: The columns are left out of this paper's scope

Source: Make and Deliver

Figure 5
Planning processes suitable to perform on a collaborative basis



Collaborative supply planning
A lot of time and effort has been spent on analysing how to synchronize demand and supply in SCM research. When the collaborative demand plan has been agreed on, collaborative supply planning is the process that has to ensure that the demand plan can be fulfilled. The purpose of supply planning is thus to determine the production and purchasing requirements in order to meet the demand plan (Hoque, 2000). Most likely the collaborative demand and supply planning processes will be iterative, due to constraints and changing demand patterns within the supply chain. The collaborative supply planning structure shows great similarities with the collaborative demand planning structure. The same parties are likely to take part in the collaboration, e.g. a manufacturer performs demand planning with its retailer or distributor as well as the retailer or distributor performs supply planning with the manufacturer.

Collaborative promotion planning
Collaborative promotion planning is performed in order to establish a consensus plan for promotion activities. When there are price discounts, companies or customers tend to buy in larger quantities than needed and keep goods in stock until the inventory has depleted. This affects the demand pattern and does not reflect actual consumption which, in turn, contributes to demand amplification and less accurate forecasting (Lee *et al.*, 1997). Hence, companies should be interested in collaborative promotion planning for reasons such as reducing inventory levels and making better forecasts as a result of reduced uncertainty. However, if collaborative demand and supply planning is carried out properly, this would reduce the need for a collaborative promotion planning process. Hence, promotion planning will not be further analysed in this paper.

Collaborative transportation planning
Transportation planning includes activities to ensure that materials and finished goods will be delivered at the right time and to the right place, according to the planning schedule (Kalakota and Robinson, 1999). Collaborative transportation planning, typically incorporating suppliers, customers and carriers, would be more suitable on a vertical marketplace, where the members strive for a stable collaborative environment concerning systematic transactions of direct inputs. Since horizontal marketplaces mainly focus on operating inputs, either through spot or systematic transactions, the supplier and especially the customer may not be willing to develop a close relationship. This is due to the fact that the price is often the order winner (Hill, 2000) for operational inputs, giving the customer minor incentives to choose only one supplier for a specific operational input.

VICS has developed a concept for collaborative transportation management (CTM), defined as a process based on the same concept as CPFR (VICS, 2000a, b). CTM has additional information and steps for carriers and extends the steps of order confirmation in CPFR, which continues through shipment delivery and payment to carriers.

Collaborative product development
In recent years, there has been an increasing focus on concurrent, or simultaneous, engineering to shorten product development lead times, and thus the time-to-market for new products. Collaborative product development processes is one way to meet the intense competition (Nishiguchi, 1996). In collaborative product development all participating organizations must coordinate their activities simultaneously, wherefore the key issue is communication and information sharing (Ragatz *et al.*, 1997). Hence the Internet is an important facilitator for this process (Davenport and Prusak, 1998). However, product development in itself is a huge area and a considerable amount of research is being carried out on concerning collaborative efforts in inter-firm environments using the Internet (Hameri and Nihtilä (1997), Olin *et al.* (1999), and Tiwana and Ramesh (2001)). Therefore, the collaborative product development process is left out of the scope of this paper.

Collaborative performance management
The focus has so far been on collaborative planning processes. The collaborative planning processes are well suited to integrate on an electronic marketplace with information exchange between the supply chain members concerning demand, capacity, etc. However, it is also important to share information about performance with the rest of the supply chain. An electronic marketplace is an excellent facilitator for supply chain monitoring and sharing performance metrics. Using electronic marketplaces in a collaborative process would make it easier to update the metrics. Furthermore, metrics would also be accessible for all members in the supply chain. Yet, this requires stable relationships in the supply chain, wherefore vertical marketplaces would be most appropriate for collaborative performance management.

Bechtel and Jayram (1997) state that by sharing performance metrics with the other members of the supply chain, two goals are achieved. First, the focal company of the supply chain can see how the chain is performing overall, and if performance is poor, the company can analyse the measurements on individual supply chain members with integrated measures. Second, the focal company will also get an incentive to work with other members to increase performance for the whole supply chain. Similar ideas are put forward by Cooper *et al.* (1997), Lee and Whang (1998), and Bowersox *et al.* (1999). Furthermore, the Supply Chain Council stress the importance of performance management by defining performance metrics for supply chain reliability, supply chain responsiveness, supply chain flexibility, supply chain cost, and supply chain asset management (SCC, 2000).

Collaborative supply chain planning scenarios

Figure 6 sums up the identification of typical collaborative supply chain planning processes. The focus has been narrowed from the many supply chain processes identified above to three collaborative supply chain planning processes that will be analysed further:

1 collaborative demand planning;
2 collaborative transportation planning; and
3 collaborative performance management.

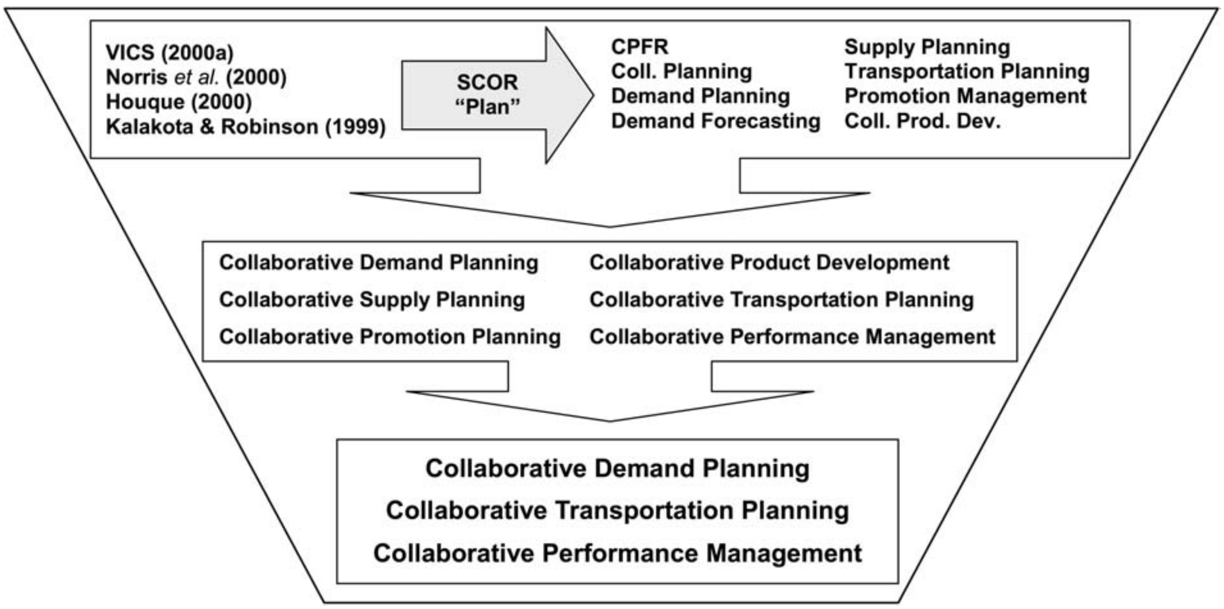
To obtain a deeper understanding of how electronic marketplaces can enhance supply chain planning, two researchers were assigned to develop collaborative scenarios for these three processes. The project was carried out in collaboration with SAPMarkets, a subsidiary of SAP AG, which develops e-business solutions together with CommerceOne and is reported in Klingenberg and Kronhamn (2001). The project focused on supply chain scenarios on an electronic marketplace. A Web-based click-through demonstration of the scenarios was also developed. It was furthermore agreed on that the researchers would use SAP concepts and terminology to define and illustrate the collaborative business scenarios.

In the following section the respective scenario for collaborative demand planning, collaborative transportation planning, and collaborative performance management are presented. It is assumed that these scenarios work in stable settings and that all three processes are used in systematic transactions of direct inputs on vertical electronic marketplaces.

Collaborative scenarios

To enable full supply chain integration using Internet technologies, there is a need to map, standardise, and integrate data and information at three levels; namely, physical system integration, application integration, and business integration (Vernadat, 1996; Gulledge and Sommer, 2001). Physical system integration essentially concerns system communication; that is, interconnection and

Figure 6
Narrowing the focus of this study



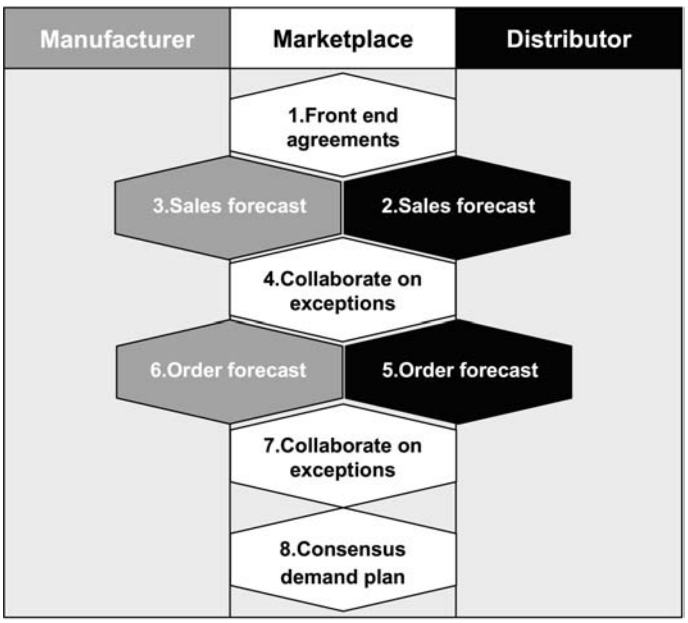
data exchange by means of computer networks and communication protocols (such as XML, TCP, IP, etc.). Application integration concerns the interoperability of applications on heterogeneous platforms. Finally, business integration deals with the integration at the enterprise level concerning business process coordination. This paper deals with the latter, i.e. integration at the business process level. A comprehensive account for enterprise integration at all three levels is provided in Rudberg and Selldin (2002).

From the perspective of business process integration, a collaborative business scenario is a predefined process of activities between companies and/or within a company. Furthermore, every collaborative supply chain scenario should identify the following:

- The parties involved, e.g. the supplier and its customers.
- The tasks that are performed, e.g. making a bid.
- The specific roles within the process, e.g. the purchasing agent and the customer service representative.
- The information flow between the parties within the process.
- Benefits that should result from the collaboration within the specific scenario.

This section presents the three scenarios for collaborative demand planning, collaborative transportation planning, and collaborative performance management. Collaborative activities naturally involve at least two members of a supply chain. The commitment made by each member may be determined by the risk and reward structure described in Lambert *et al.* (1998). It is important that the supply chain members define how to share risks and rewards before entering collaboration. Descriptions of the collaborative scenarios follow in the proceeding sections.

Figure 7
Collaborative demand planning



Collaborative demand planning

In the following, the parties, tasks, roles, and information flows for the collaborative demand planning scenario are defined. Furthermore, some assumed benefits from the collaboration, using an electronic marketplace, are presented.

The parties involved in collaborative demand planning should include all of the primary members in the supply chain (Lambert *et al.*, 1998). Preferably, the collaboration should take part two-by-two between adjacent nodes in the supply chain, e.g. between the manufacturer and its distributor or between the distributor and its customer. To assign the typical tasks within the scenario, SAP concepts in combination with the CPFR-model (VICS, 2000a) are used. The result of the collaboration will be a consensus demand plan. The specific tasks that were identified are shown in Figure 7.

As already stated before, a specific role has to be assigned within every task. Certainly, the title of these roles would vary from company to company but possible roles in this scenario would be a demand planner for the manufacturer and an account manager or supply planner for the distributor. In this scenario they will be responsible for all of the tasks for their respective company. The information flow in the collaborative demand planning scenario includes all the necessary information to support the tasks. For every task in this scenario, possible information that will be exchanged between the parties is given in Table III.

The manufacturer is assumed to experience reduced uncertainty in demand and hence more accurate demand forecasts due to the information exchange with the distributor. As a result, from reduced uncertainty, the manufacturer will have the possibility to lower its safety stock. The improved order forecast allows the manufacturer to allocate the capacity in advance and therefore improve the utilization. By receiving information about customer demand more rapidly, the manufacturer will be able to produce the right product to be delivered at the right time. Since the distributor gains increased confidence that the right orders will be

Table III
Tasks, roles, and information flow in the demand planning process

1. Front end agreements	The purpose of front-end agreements is to establish goals and objectives to give the partners a joint blueprint for starting the collaborative relationship. The agreement should also include a decision concerning the necessary information sharing to support the process. It is also important that the parties define the forecast horizon and the frozen forecast period, where the shared forecast becomes a firm order
2. and 3. Sales forecast	In order to create a sales forecast, the distributor and manufacturer use historical data, POS and planned events, e.g. promotion plans. The distributor and manufacturer create their own sales forecast with forecasting software for a given period, using the information mentioned above
4. Collaborate on exceptions	The manufacturer receives the sales forecast from the distributor and identifies possible exceptions and updates the joint forecast. The forecast is then sent back to the distributor. This is an iterative process, which continues until both parties are satisfied and a joint sales forecast is decided on
5. Order forecast distributor	The distributor compares the joint sales forecast against POS and its own on-hand inventory to generate an order forecast. The generated order forecast should contain information about the order volume and delivery dates
6. Order forecast manufacturer	The manufacturer receives the distributor's order forecast. In order to identify exceptions in the forecast, the manufacturer analyses internal capacity limits, historical demand and current inventory levels
7. Collaborate on exceptions	The manufacturer updates the order forecast to meet the identified exceptions and returns the modified forecast to the distributor. The distributor then examines the forecast and resolves its own exceptions. This process continues until both parties have agreed on a joint demand forecast
8. Consensus demand plan	When both parties have agreed on a joint demand forecast it becomes the consensus demand plan, where the plan within the frozen forecast period will generate firm orders

delivered at the right time the safety stock could be reduced. The improved delivery accuracy enhances the possibilities for the distributor to improve the delivery processes for its own customers and thereby to provide better customer service.

Collaborative transportation planning

In the following, the parties, tasks, roles, and information flows for the collaborative transportation planning scenario are defined. Furthermore, some assumed benefits from the collaboration using an electronic marketplace are presented.

As in the previous scenario, the collaborative transportation planning should preferably take place between two adjacent nodes in the supply chain. The parties could be the same as in the collaborative demand planning scenario, i.e. the manufacturer and the distributor, but with an additional actor included, e.g. the carrier. Worth noticing is that in this scenario some parties would need additional technology; for instance, the carrier may need additional communication tools for the trucks, e.g. an online personal digital assistant (PDA) and a global positioning system (GPS), to communicate with the electronic marketplace. To assign the typical tasks within this scenario, SAP concepts and the CTM-model (VICS, 2000b) were used. The specific tasks that were identified are shown in Figure 8.

The roles involved in this scenario could indirectly involve more than one employee for some of the tasks. However, the primary responsible roles should include the transportation manager or transportation planner for the manufacturer and distributor, together with a transportation specialist from the carrier. Information that needs to be exchanged is described in Table IV.

The collaboration between the parties give them opportunities to create more accurate shipment forecasts and react to demand variations at an earlier stage. This will give the parties a possibility to better plan their asset utilization, which will reduce the overall cost. The extended information sharing will result in improved forecasts and increased visibility throughout the supply chain. Consequently, this will result in more reliable deliveries and in the end, improved service levels and customer satisfaction.

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Niklas Klingenberg and
Kristoffer Kronhamn
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Collaborative performance management

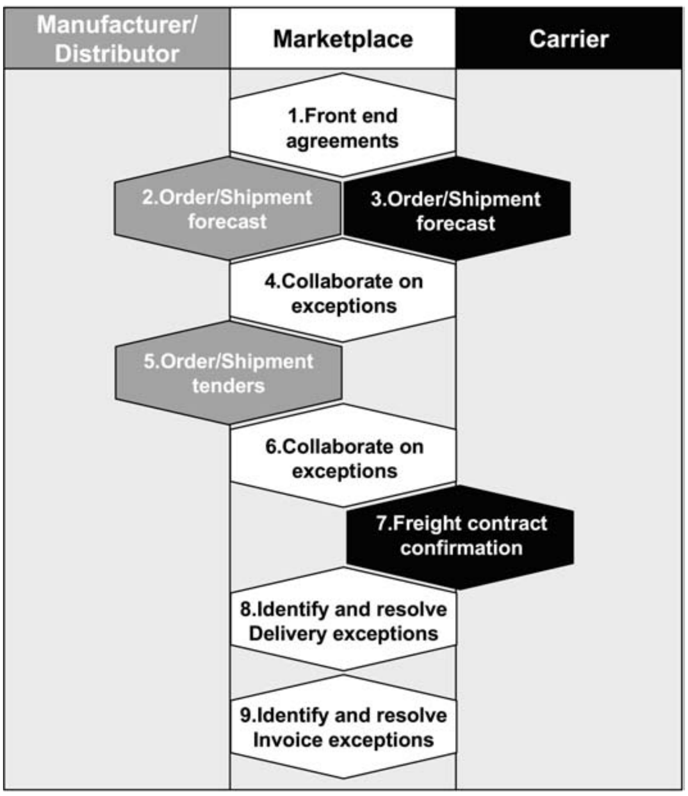
The collaborative performance management scenario is considered as a scenario to monitor and improve the overall supply chain performance. This scenario can be integrated with other business scenarios to observe the performance of individual processes. The SCOR-model (SCC, 2000) is used as well as SAP concepts when identifying relevant activities within this process. In the following, the parties, tasks, roles, and information flows for the collaborative performance management scenario are defined. Furthermore, some assumed benefits from the collaboration using an electronic marketplace are presented.

Collaborative performance management should include all of the members in the supply chain, or at least as many as possible, to give an indication of the overall performance. The process flow is intended to begin with an analysis of the performance, followed by identification of weaknesses, which will serve as a basis for the final improvement plan (see Figure 9).

Since this is a scenario to improve and control the overall supply chain performance, the supervising role for each member in the supply chain should be the supply chain manager. However, in order to perform certain tasks, a supply chain manager could use other employees with specific knowledge, e.g. to create improvement plans for lead-time reductions, etc. The information flow in collaborative performance management mainly concerns performance metrics, but also includes goals and strategies of how to improve performance. The scenario begins with a front-end agreement to establish a foundation for the collaboration and ends with a consensus improvement plan, see Table V.

The benefits from collaborative performance management originate from improved supply chain control. By monitoring and evaluating performance to identify and eliminate the weaknesses of the supply chain, performance will continuously improve. Consequently, the cost will be reduced and customer service increases due to more efficient management of the supply chain. Finally, by measuring the overall performance, the supply chain can benchmark its own performance against competing supply chains.

Figure 8
Collaborative transportation planning



The Web-based demonstration

SAPMarkets creates Web-based customer demonstrations for marketing purposes to show how the collaborative business scenarios can be used. These demonstrations contain fictitious companies and roles to make the scenarios more realistic. The demonstrations are usually interactive so that the user can obtain a feeling for how one would actually perform tasks in the business scenario. A short description of the collaborative demand planning demonstration is presented in the following[1]. Note that the demonstration is typical with the purpose of showing how collaborative demand planning could be performed using an electronic marketplace. The demonstration should not be seen as normative guidelines of how collaborative efforts must be performed.

The customer demonstration contains five steps performed by the individual parties within this scenario. After the front-end agreement is established the demand planner at the manufacturer logs on to the private electronic marketplace and starts the collaborative demand planning process (step 1). The demand planner sends e-mail to the distributor, indicating that it is time to review the sales forecast. The e-mail contains a link to the common planning book, which is integrated with each respective firm's ERP backbone system. In the planning book the account manager at the distributor reviews the statistical forecast and makes necessary adjustments. Exception alarms and alerts are

Table IV
Tasks, roles, and information flow in the transportation planning process

1. Front end agreements	First, the manufacturer, carrier and distributor jointly establish an agreement to collaborate. They define the relationship regarding freight terms, products, locations, types of shipments, capacity and how to manage exceptions
2. and 3. Order/shipment forecast	Based on the manufacturer's order forecast, which preferably has been created through collaborative demand planning, a shipment forecast is created. Separately, the carrier creates a forecast, based on order history, POS and the manufacturer's and distributor's inventory levels
4. Collaborate on exceptions	The carrier receives the manufacturer's shipment forecast and identifies possible exceptions. The forecast is sent back to the manufacturer, who reviews the changes and updates the forecast. This iterative process continues until the parties agree on a joint shipment forecast
5. Order/shipment tenders	The manufacturer creates a shipment tender, based on the resolved shipment forecast. The shipment tender contains information about definite order volumes as well as pickup and delivery requirements
6. Collaborate on exceptions	The carrier receives the shipment tender and identifies exceptions. The carrier, together with the manufacturer and distributor, collaborate until the tender is accepted
7. Freight contract confirmation	As a result of the accepted tender, final shipment contracts for specific freight orders are created
8. Identify and resolve delivery exceptions	The carrier sends an advanced shipping notice (ASN) to the distributor about shipment attributes of the freight orders, e.g. weight, line items, freight classes, assessorial and shipment status. If any exceptions occur, the resolution is handled interactively between the parties
9. Identify and resolve invoice exceptions	Sometimes, the traditional payment process can cause a difference of opinion regarding the shipment attributes in step 8, and hence, the invoice. The parties have to collaborate until this difference of opinion is resolved

generated automatically by the system. Finally, the distributor sends the modified forecast back to the manufacturer for further reviewing.

In step 3, the demand planner at the manufacturer receives the sales forecast from the distributor. The demand planner reviews the sales forecast and makes necessary forecast adjustments to eliminate any alert messages generated by the system. Finally, the demand planner confirms his changes to let the system create a new consensus forecast. In this process they develop a joint sales forecast based on combined promotion calendars, POS data, etc., and resolve any forecast exceptions. In the fourth step, the distributor's account manager receives the consensus forecast from the manufacturer. The account manager reviews the consensus forecast and makes necessary forecast adjustments to meet constraints in capacity concerning specific orders. Finally, the modified order forecast is sent back to the manufacturer for confirmation or further reviewing. In this process the manufacturer and the distributor develop an order forecast that time phases the sales forecast while meeting the business' objectives and constraints.

Before turning to some concluding remarks, it is important to point out that the scenario described above is just one possible way of how collaborative demand planning could work and look like. It was used to show how the functionality of an electronic marketplace could be used to facilitate collaborative supply chain planning. It is also important to note that the use of SAP was for demonstration purposes only. The collaborative supply chain scenarios could just as well have been implemented using other software providers, such as Baan, i2, IBM, IBS, Manugistics, Oracle, etc. (for more information on software providers dealing with supply chain integration and the Internet, refer to, e.g. AMR, 2000a, c; and Gulledge and Sommer, 2001).

Concluding remarks

The globalisation of markets and manufacturing has increased competition and brought forward an inter-enterprise environment. Today, competition in many industries is between supply chains and not just between individual firms. Consequently, there is a need to collaborate between supply chain members and share accurate and timely information with both upstream and downstream supply chain partners. This, in turn, creates visibility and offers possibilities to synchronise supply chain planning activities, which will reduce uncertainty, bullwhip effects, inventory, etc. Collaborating by using electronic marketplaces facilitates information sharing and is less expensive and more flexible than EDI networks. It also offers easy access through Web browsers and can be integrated with each member's existing ERP backbone.

The purpose of this paper was to show how the functionality of electronic marketplaces could facilitate collaborative SCP. SCP processes with a SCM focus have been identified and analysed. Six collaborative SCP processes were identified. Three of these processes were analysed further by means of defining typical collaborative scenarios. A Web-based demonstration was used to show how these scenarios could be implemented on an electronic marketplace.

Today, many of the existing electronic marketplaces cannot provide all necessary value-added services to the supply chains. In order to become successful, electronic marketplaces will have to develop the functionality and value-added services, such as integrating supply chain collaboration, electronic workflows and transactional capabilities (AMR, 2000c). The success of electronic SCM (e-SCM) depends on two aspects. First, how well the collaboration works among the supply chain members and, second, how well the information visibility is managed across the supply chain. The key issues when establishing supply chain collaboration are to determine what information that should be shared among the supply chain partners and how to make that information available to all parties (Lummus and Vokkurka, 1999). By synchronising

Figure 9
Collaborative performance management

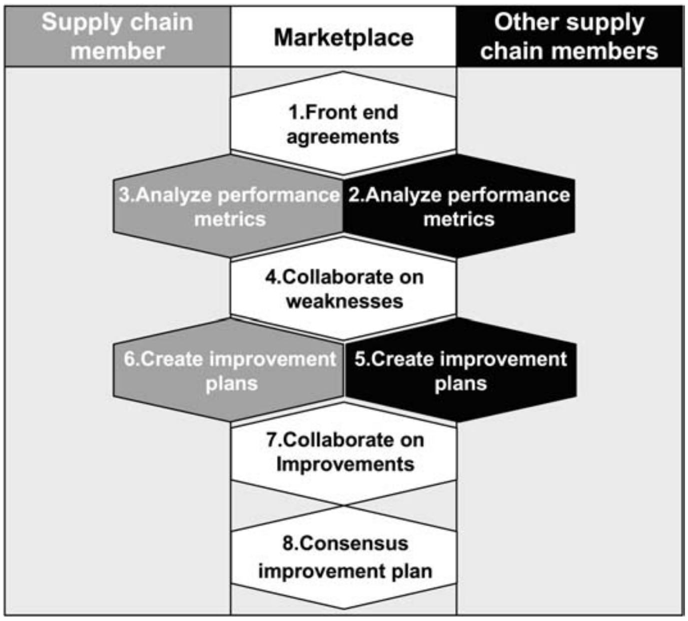


Table V
Tasks, roles, and information flow in the performance management process

1. Front end agreements	Initially, the supply chain members should establish a front-end agreement, where the overall objectives are defined and relevant performance metrics are determined. The objectives should comprise short and long-term goals for the overall performance levels in the supply chain, as well as for each individual member
2. and 3. Analyse performance metrics	The members analyse their own metrics as well as relevant metrics from other members. This is done in order to identify performance weaknesses in the supply chain
4. Collaborate on weaknesses	The members exchange their results of identified weaknesses, both on their own performance and the overall supply chain performance. Since the supply chain needs to improve the overall performance the members have to collaborate to identify where to distribute resources for further improvements
5. and 6. Create improvement plans	Based on the joint decision about which weaknesses to improve, the members develop an improvement plan. The improvement plan should include information about which members to include and how they should proceed with the improvement process
7. Collaborate on improvements	Based on each member's improvement plan, a joint decision is taken about an overall plan for improvements. Since each member will probably not be satisfied with the first proposal to an improvement plan they will have to collaborate to find an acceptable solution
8. Consensus improvement plan	When the members have accepted the improvement plan it should be published on the electronic marketplace and the performance should continuously be evaluated so that the improvements will be realised

supply and demand information across the supply chain, companies can reduce their inventories, eliminate stocking points and distribution steps, and increase the speed of replenishment.

This paper has focused on SCP processes. Further research is required to investigate how supply chain execution processes can benefit from e-business solutions. Furthermore, only three of the six collaborative processes identified in this report were analysed. A natural next step is to analyse the remaining processes. There is also a need to analyse how the electronic marketplaces actually work and if they provide all those benefits they proclaim to incorporate. Hence, research on using electronic marketplaces for SCM purposes is in its infancy with many interesting dimensions to be further investigated in the future.

Note

1 The demonstration package for the collaborative demand planning scenario can be accessed in full at: www.ipe.liu.se/SAP/cscp.htm

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