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Requirements for forming an 'e-supply chain'

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In today's digital economy, web-based integration of the enterprises to form an e-supply chain is a critical weapon for orchestrating the whole supply chain towards competitiveness. This paper intends to discuss the requirements for forming an e-supply chain from different perspectives, such as integration with the legacy systems, timing and prior presence of ERP (enterprise resources planning) systems, BPR (business process re-engineering) needs of internal and external business processes and business intelligence/decision support needs. A look at technical knowledge and structure to construct an e-supply chain is provided. Challenges involved in forming an e-supply chain are also briefly mentioned as a separate section in this paper. During the study, requirements are gathered by making a review of recent literature.

Keywords: e-supply chain; ERP (enterprise resources planning); BPR (business process re-engineering); requirements; challenges

1. Introduction

A 'supply chain' is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers (Rehan 2006). Recent technological developments in information systems and technologies have the potential to facilitate the coordination among different functions, allowing the virtual integration of the entire supply chain. The focus of this integration in the context of Internet-enabled activities is generally referred to as e-SCM (e-supply chain management), merging the two fields of SCM and the Internet. E-SCM will refer to the impact that Internet has on the integration of key business processes from end user through original suppliers that provide products, services and information that add value for customers and other stakeholders (Gimenez and Lourenço 2004).

Supply chain dynamics have been studied for more than three decades. Huang *et al.* (2003) and Chen and Paulraj (2004) classify approaches and initiatives within the scope of SCM (supply chain management) into four streams of research efforts:

- Strategic purchasing.
- Supply management.

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- Logistic integration.
- Supply network coordination.

A supply chain is more practically defined as a 'connected network which typically crosses organization boundaries' (Chen *et al*. 2004). The supply chain encompasses every effort involved in producing and delivering a final product or service, from the supplier of raw materials to the customer. Due to its wide scope, supply chain management must address complex interdependencies, such as those in the form of 'extended enterprise' (Muffato and Payaro 2004).

In previous research by Themistocleous *et al*. (2004) it is mentioned that future competition will not be company against company but rather supply chain against supply chain.

Viswanadham and Gaonkar (2006) define an 'integrated supply chain network' as a group of independent companies, often located in different countries, forming a strategic alliance with the common goal of designing, manufacturing and delivering right-quality products to customer groups faster than other alliance groups and vertically integrated firms'.

This paper will focus on requirements for forming an e-supply chain with the following objectives:

- Identifying the need and importance of the e-supply chain.
- Establishing the relationship of the topic with the legacy systems and ERP systems in terms of integration requirements, precedence/order of the implementation.
- Identifying basic requirements to form an e-supply chain.
- Investigating different technologies used for forming an e-supply chain, by comparing and contrasting them.
- Identifying technical and managerial challenges involved in establishing e-supply chains.

The methodology selected in the study is the review of recent e-supply chain literature. The scope of the paper covers both technical and managerial aspects of the e-supply chain, with special emphasis on integration. Besides newcomers to the field of e-SCM, people from ERP and supply chain domains are among our targeted audience.

After defining an e-supply chain in Section 2, Section 3 discusses why an e-supply chain is required, with a detailed discussion of different models of integration in Section 4. Section 5 analyses the requirements for an e-supply chain from different perspectives, such as the existing legacy systems, integration with the ERP systems, and the need for re-engineering and collaborative planning. Section 6 takes a look at technical knowledge and structure for building an e-supply chain and Section 7 mentions the technical and managerial challenges involved in forming an e-supply chain.

2. Definitions

With the recent trends of globalisation, competitiveness, stunning developments in information technology and the use of the Internet, more and more transactions are performed on the Internet and it is becoming critical for the firms to rely on 'web-based supply chains' or 'e-supply chains' (Pant *et al*. 2003). The Internet is becoming a more cost-effective and powerful medium for doing business (Rehan 2006), leading to the concept of the 'e-supply chain' in which efficiency and effectiveness of the overall supply chain is increased via 'web-based' connectivity of inter-organisational information systems (Viswanadham *et al*. 2006).

In Luo *et al*. (2001), an e-supply chain is defined as 'an emerging business strategy that incorporates the power of e-commerce to streamline the manufacturing processes, speed the product cycles, and integrate the supply chain and better response to customers'. The paper also defines an integrated e-supply chain network as a 'hyper network of material flows overlaid with an e-business information network'. Therefore, e-supply chains materialised from the application of Internet technologies in the management of supply chain interactions.

A schematic of the highly integrated supply chain is given in Figure 1, as adopted from Pant *et al*. (2003), showing the integration among different parties on the supply chain. In this figure, supplier, customer and distributor systems are integrated with the manufacturer's system via the Internet. In its generalised form, we can talk about a number of suppliers, customers and distributors interacting with the manufacturer with similar web-based connectivity, thus forming a network.

Chen *et al*. (2004) define an e-supply chain as a 'highly integrated supply chain with electronic links based on the Internet'. The complexity and the degree of integration with the suppliers and distributors differ and we can talk about 'highly integrated' and 'partially integrated' e-supply chain systems, as given in Pant *et al*. (2003). The paper shows that in highly integrated web-based supply chains we observe complexity for both internal and external operations and the clear need for integrating internal systems via ERP systems. As well as integrating internal operations through standard ERP packages, external connectivity is needed. As partial integration example, the paper mentions web-based ordering and focusing on eliminating both internal and external efficiencies related with ordering process.

3. Aims and benefits of forming e-supply chain

In today's digital economy, flexibility, adaptation and responsiveness are critical to success. The Internet is the greatest ICT (information and communication technology)

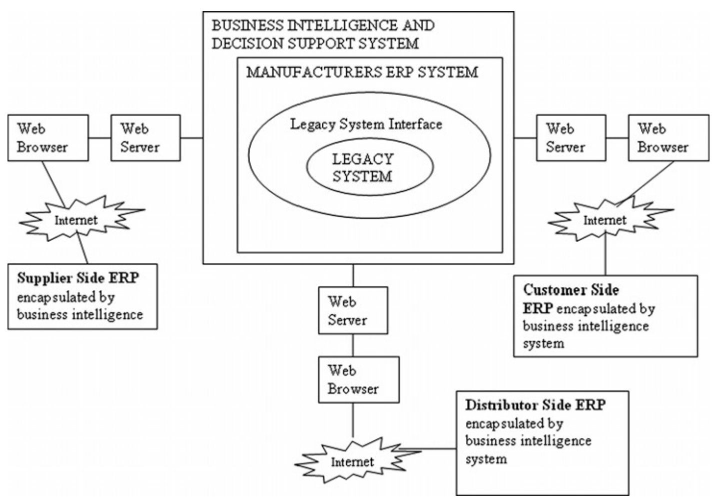

Figure 1. Schematic of highly integrated supply chain. Source: adapted from Pant and Sethi (2003).

tool, and 'integration' is the key to efficiency and success; e-supply chains take advantage of the Internet to obtain better integration over the supply chain. Therefore, the reasons for forming e-supply chains are as follows:

- Effectively leveraging web to redesign, automate and integrate all business functions.
- Seamless coupling to the entire supply chain via the web, with strong internal as well as external integration.
- On-line, real-time collaboration and synchronisation via the web.

The benefits of realising these aims by forming a web-based supply chain are evident in the literature. In Luo *et al*. (2001) the following are clearly emphasised for e-supply chains and internet-enabled, shared information:

- Brings about a 'more cooperative' business environment.
- Facilitates 'more interactive approach to supply chain'.
- Provides demand data and supply capacity data visibility.
- Provides ability to anticipate and respond to demand fluctuations.
- Provides tools for tightly orchestrating the relationships across the entire supply chain.
- Helps creating operational linkages.
- Helps creating strategic partnerships.
- Helps in breaking down the organisational and functional fences.
- Enhances the flow of information.

In Pant *et al*. (2003), the following appear as the benefits of forming an e-supply chain:

- Streamlining both internal and external operations.
- Ability to provide real-time response to market conditions.
- Ability to provide real-time response to customer queries.
- Ability to undertake real-time, joint demand planning.

In Rehan (2006), the greatest advantages mentioned are as follows:

- Obtaining cost savings through integration of the supply chain.
- Overall reduction in the inventory levels throughout the supply chain.
- Reduction in procurement costs.
- Improved vendor management.
- Cycle time reduction.
- Improved profitability.

4. Different models of integration

In the literature, there are various definitions and models for integration. Themistocleous (2004) reports that 'an enterprise is no longer viewed as a single corporation but it is a loose collection of trading partners that can contact with manufacturers, logistic companies and distribution organisations'. Therefore, the need for comprehensive integration of business processes and both intra- and inter-organisational applications are clear to support long-term coordination, survival and growth.

Bendoly and Jacobs (2005) define integration as 'connecting information systems and bringing about common information and processes together throughout an organisation'.

Xu *et al*. (2005) refer to previous work by Romano (2003), mentioning that 'integration can be regarded as a mechanism to support business processed across a supply network at two different levels: intra- and inter-company integration'.

Themistocleous *et al*. (2004) discusses the limitations of ERP systems in handling the inter-organisational integration and the need for building a common EAI (enterprise application integration) that unifies all the information systems. The paper proposes a generic structure which integrates legacy, ERP and e-business systems of different parties throughout the supply chain and defines 'loose' and 'tight' types of information, similar to 'high' versus 'partial' integration previously defined in Pant *et al*. (2003). While making the 'loose' and 'tight' distinction, the degree of process dependency (low versus high), degree of integration (low versus high), type of communication (synchronous versus asynchronous) appear as the critical factors. The basic characteristics of loose and tight types of integration, as defined by them, are summarised in Table 1.

Campbell and Sankaran (2005) mention integration about customers, internal functions, activities, suppliers, technology, planning, measurement systems and relationships, emphasising that 'it is well documented in the literature that the lack of integration between members of a supply chain results in operational inefficiencies that compromise the performance of the supply chain'. In their literature survey, they clearly indicate that both internal and external integration needs have to be considered.

Previous research by Burnell (1999) and Stock and Lambert (2001) is referred to in this paper, emphasising 'focus on integrating the internal supply chain is necessary before an organisation attempts to integrate its business partners'. The idea that 'a company needs to have "its own house in order" before trying to integrate with its trading partners' is recapitulated.

All these ideas are also supported by Bendoly and Jacobs (2005), who refer to the 'supply chain compass', a supply chain evolution model developed by Fox and Holmes (1998). This model, given in Table 2, defines five stages of evolution for a supply chain, starting with fundamental functions running with independent departments at stage I, becoming consolidated at stage II, assuring internal integration at stage III, reaching external integration within the extended supply chain at stage IV, then moving towards network-centric commerce at stage V.

This model implies that the evolution of the supply chain is a staged process and that an organisation needs to integrate internally before it evolves to a more advanced stage of external integration (Campbell and Sankaran 2005).

Table 1. Basic characteristics of loose and tight types of integration.

Loose integration	Tight integration
Focus on exchanging/sharing data among partners	Focus on integrating cross-enterprise business processes and systems
Low degree of process dependency	Highest degree of process dependency
Low degree of integration	High degree of integration
The development of an homogenous, integrated cross-enterprise infrastructure NOT critical	The development of an homogenous integrated cross-enterprise infrastructure critical
Asynchronous communication	Synchronous communication

Source: Pant and Sethi (2003).

Table 2. Stages of supply chain evolution – as defined by Fox and Holmes (1998).

	Stage I The fundamentals	Stage II Cross-functional teams	Stage III Integrated enterprise	Stage IV Extended supply chain	Stage V Supply chain communities
Business pain	Cost of quality	Unreliable order fulfilment	Cost of customer service	Slow growth margin erosion	Non-preferred supplier
Driving goal	Quality and cost	Customer service	Profitable customer responsiveness	Profitable growth	Market leadership
Organisational focus	Independent departments	Consolidated operations	Integrated supply chain(internal)	Integrated supply chain (external)	Rapidly reconfigurable
Process change	Standard operating procedures	Cross-functional communications	Cross-functional processes	Customer-specific processes	Reinvented processes
Metric	Predictable costs and rates	On-time, complete delivery	Total delivered cost	Share of customer	New worth
IT focus	Automated	Packaged	Integrated	Inter-operable	Networked
Key planning tools	Spreadsheets	Point tools	Enterprise supply chain planning	Point-of-sale supply chain planning	Synchronises supply chain planning
Key execution tools	MRP and other home-grown applications	MRPII	ERP	Customer Management Systems	Network-centric commerce

Source: Bendoly and Jacobs (2005).

Muffato and Payaro (2004) define five stages for e-business:

- Traditional communication tools.
- Internal integration.
- Web-based communication tools.
- XML (extensible mark-up language) web-based platform.
- Integrated enterprise.

Parida and Parida (2005) mention seven different e-procurement models during e-evolution, based on Kalakota and Robinson (2000), as follows:

(1) EDI (electronic data interchange) networks.
(2) B2E (business-to-employee) requisitioning applications.
(3) Corporate procurement portals.
(4) First generation trading exchange: community catalogues and storefronts.
(5) Second generation trading exchange: virtual distributor auction hubs.
(6) Third generation trading exchange: collaborative supply chains in the form of trading collaboration hubs.
(7) Industry consortiums: joint venture collaboration hubs.

Hayes (2004) categorises e-supply chain solutions ranging from 'open' to 'closed', based on the level of integration. Within this range, he mentions ERP systems, EDI, custom interfaces with trading partners, web storefronts, intranet-based procurement systems, e-market places (trading hubs), trading exchanges and collaboration platforms. Basic characteristics, advantages and disadvantages of these solutions are as follows:

- EDI is limited data sharing among ERP systems via custom interface implementations. Although it eliminates a lot of paperwork, speeds up transactions and enables encryption, EDI has disadvantages of having different subsets of standards, lack of semantic rigour in the meaning of various components of EDI messages, formal agreement requirement on mutually acceptable definitions and having high start-up and maintenance costs. Besides these disadvantages, EDI messages are unable to interface with semantic web services since they are not semantically-enabled (Foxvog 2005). In this regard, Lan (2005) mentions advantages of using XML over standard EDI technologies in terms of cost effectiveness and flexibility to implement and operate. A previous work is referenced by Nurmilaasko *et al.* (2002) to emphasise the suitability of XML over EDI technologies. Drawbacks and shortcomings of EDI for e-supply chains are also mentioned in Viswanadham and Gaonkar (2006), such as cost of maintenance and requirement of forming dedicated links, restricting on-demand, and dynamic link formation among new supply chain partners.
- Custom interfaces rely on extranets or virtual private networks implemented on a custom basis and they rely on outside consulting assistance (Hayes 2004).
- Web storefronts are mentioned as a non-classical example of an e-supply chain solution with special focus on the seller side (Hayes 2004).
- Corporate procurement systems are reported to have the basic focus of procurement, with significant cost of implementation and maintenance (Hayes 2004).
- Trading hubs are emphasised as supporting many-to-many relationships among trading partners and covering functions of e-catalogues, dynamic pricing, conducting auctions, financial settlement, fulfilment and logistics (Hayes 2004).

- Collaboration platforms in this classification are based more on collaboration and coordination of the partners and they include collaboration in the areas of design, forecasting, planning and replenishment (Hayes 2004).

Basing on these discussions about integration models, it is clear that naming, numbering of the evolution stages are various in the literature. The following points are evident and common for these models:

- Presence of a staged evaluation process.
- Increased degree of collaboration and dependence among supply chain partners, with decreased autonomy of decision making.
- The need for internal integration within the corporate before evolving into collaborative integration in the form of e-based supply chains.
- Change towards portal based structures to enable collaboration.

Therefore, it is clear that an e-supply chain is a major step beyond internal integration and many orchestrating effects come along with the achievement of the external integration.

5. Requirements for forming an e-supply chain

In the literature, the following appear as the main requirements when forming an e-supply chain:

- Replacement of or integration with the legacy systems.
- Standardising and streamlining internal processes – BPR/redesign if needed.
- Adoption, updating or integrating with the existing ERP of the enterprise.
- Streamlining external processes – BPR/redesign if needed.
- Collaborative planning and joint management of key business processes.
- Business intelligence and decision support.

In this paper, all of the above items will be analysed with respect to past research.

5.1 *Replacement of, or integration with, the legacy systems*

The presence of legacy systems is inevitable in organisations and these systems may sometimes contain mission critical data, with millions of lines of codes. Although replacement of these systems is necessary for many reasons – such as technology in which they are written becoming obsolete and unsupported or suppliers withdrawing support – totally abandoning these systems by replacing them with new alternative information systems or rewriting these systems is not always possible. This is because some of the functionality and data present in the legacy systems may still be needed, maybe even mission critical, and legacy systems may contain the details of the vital processing algorithms (Bennett *et al.* 2006). Therefore, a way to access the critical data present in the legacy systems is required. Bendoly and Jacobs (2005) also clearly mention the need to integrate the enterprise solutions package modules with their other legacy systems. Therefore, deciding on which legacy systems to abandon and which ones to keep and integrate with enterprise wide solutions is a critical decision to be made as part of the ERP implementation. The enterprise will have problems with 'internal' integration right from the start if integration with the legacy systems is not properly handled. Thus, integrating the legacy system with ERP systems can be considered as the first step towards consolidating traditional, functional and locational 'silos' of information.

The solution to be used in accessing back-office functionality will depend on how much of the system needs to be Internet-enabled. Zoufaly (2002) suggests two basic non-intrusive approaches in this regard:

(1) Frontware (screen scrapers) is an approach used in order to deliver web access on the current legacy platform. The non-intrusive tools add a graphical user interface to character-based legacy applications, providing Internet access to legacy applications without making any changes to the underlying platform. As they are non-intrusive, screen scrapers can be deployed in days and sometimes hours. However, scalability can be an issue since most legacy systems cannot handle nearly as many users as modern Internet-based platforms.
(2) Legacy wrapping is the technology that provides a new interface using a conversion programme (wrapper) without changing the interface of the existing software. Although the interface of each legacy system differs, the wrapper will absorb the difference (Yoshioka *et al*. 1998). The technique builds callable APIs (application programming interfaces) around legacy transactions, providing an integration point with other systems. Wrapping does not provide a way to fundamentally change the hardwired structure of the legacy system, but it is often used as an integration method with EAI frameworks (Zoufaly 2002). This technique is also mentioned in Bennett *et al*. (2006), who talk about 'creating new front-ends', typically using modern GUIs and 'wrapping' these systems up in new software. In this case, wrapper design and a good understanding of the interfaces to the legacy systems are critical. This approach enables integration vendors to focus on the communications and connectivity aspects of their solutions, while avoiding the complexity of legacy systems.

Like screen scraping, wrapping techniques are applicable in situations where there is no need to change business functionality in the existing platform. However, none of the above approaches address the problems, such as high cost, associated with maintaining a legacy system or finding IT professionals willing to work on obsolete technology (Zoufaly 2002).

As a company evolves and seeks external integration with suppliers and customers, the need for considering and examining the legacy systems of the partners also becomes critical (Williamson *et al*. 2004), as the presence of legacy systems are valid for suppliers and customers as well.

5.2 *Standardising and streamlining internal processes – BPR/redesign if needed*

During ERP implementations, it is well-proven that change in internal business processes is needed towards standardising and synchronising ways of doing business for different business functions. The degree of change depends totally on the enterprise and these changes can amount to complete restructuring/reengineering of various internal business functions involved.

Bendoly and Jacobs (2005) clearly state that ERP systems enable organisational standardisation, including the standardisation among different locations belonging to the same enterprise. This results in improving ways of doing business at substandard locations, bringing them in line with others.

Standardised firm-wide transactions and centrally stored enterprise data are also referred to by Hendrics *et al*. (2007) for facilitating the governance of the firm.

The role of ERP systems for streamlined processing of business data and internal, cross-functional integration are mentioned by Gupta and Kohli (2006), emphasising the role of ERP in struggling with data redundancy, information inconsistency, incompatible information systems and inconsistent operations policies.

Therefore, it is clear that a successful ERP implementation will force organisations to standardise, restructure and streamline the 'internal' functions, all the re-engineering efforts being handled within the scope of ERP implementation.

5.3 *Implementation, adoption or updating of ERP system*

Since forming an e-supply chain requires integrating business functions beyond the enterprise boundary and assures connectivity with suppliers and customers, a sound base of integration for all in-house activities around a centralised database is needed. As such, let it be a new ERP implementation, or adaptation/updating of a previously existing ERP system, a sound ERP infrastructure system up-and-running is the greatest enabler towards forming an e-supply chain. Therefore, ERP systems become the backbone for the e-supply chain.

Enabling position of ERP systems for improvement, development and growth is also clear in the literature. In Bendoly and Jacobs (2005), the following diagram (Figure 2)

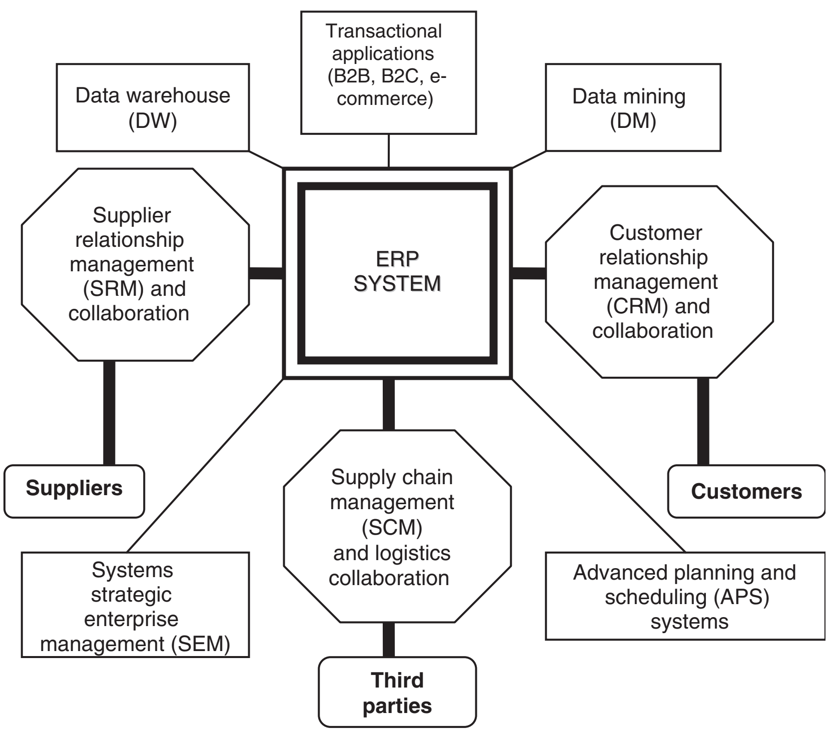

Figure 2. Enabling position of ERP for integration of different systems. Source: adapted from Bendoly and Jacobs (2005).

clearly shows the central position of ERP to integrate different systems like SCM, CRM (customer relationship management), data mining, data warehousing:

It is argued that ERP can be used to help firms create value and it is emphasised that value creation by ERP usage is attained by the following:

- Integrating firms activities.
- Enabling organisational standardisation.
- Eliminating information asymmetries.
- Providing on-line and real time information.
- Allowing simultaneous access to same data for planning and control.
- Facilitates intra-organisation communication and collaboration needs.
- Facilitates inter-organisation communication and collaboration needs, laying the foundation for external integration.

As such, a successful ERP implementation is the greatest enabler for 'extended' supply chain and appears to be a giant step passed for internal integration. In this regard, a successful ERP implementation means:

- In-house re-engineering, streamlining and standardisation efforts are completed within the scope of ERP implementation.
- Different organisational data are now ready for simultaneous access around a single database, forming the basic foundation for better internal communication and efficient on-line, real-time reporting needs.

Only after these stages are completed can we start talking about efficient external integration. Bendoly and Jacobs (2005) talk about ERP as being the 'information backbone' for communication and collaboration with other organisations. Therefore, ERP systems become the backbone for other value-adding systems like APS (advanced planning and scheduling), CRM, SRM (supplier relationship management), call centre management, e-procurement, e-auction, e-commerce, data warehouses, and project management. Bendoly and Jacobs (2005) talk about these systems as 'bolt-on' systems, taking ERP systems as the core. Among these systems, the author emphasises two systems, CRM (customer relationship management) and e-procurement, using the results of a 2004 survey questionnaire based on APICS's (American Production and Inventory Control Society) mailing list. Basing on the results of this survey, the author argues that CRM and e-procurement systems have the top ranking for implementation. These two bolt-on systems appear as the key to provide better linkages to the extended supply chain. As such, CRM improves the linkages to customers and enhances communication on the downstream side of a firm's supply chain, whereas e-procurement systems provide linkages to suppliers and strengthen relations on the upstream side of the supply chain.

Leopoulos and Kırytopoulos (2005) also treat ERP systems as 'a core component' of an extended supply chain and clearly emphasise the fact that 'ERP systems are examined as a component of e-commerce applications'. In the concluding section of their article, they strongly state that the implementation/adoption of ERP systems are 'inevitable' to operate in an e-business environment. In the ordering defined in five-stage evolution model of Muffato and Payaro (2004) mentioned earlier, internal integration of a company appears prior to e-based business integrations. This also supports the idea of internal integration around ERP prior to web-based integration.

Therefore, it can be easily argued that integration of different functions at the enterprise level around a sound ERP implementation forms the basis of extended enterprise integration in the form of an e-supply chain, with CRM and e-procurement systems having the top priority, as being the critical links at downstream and upstream sides of the supply chain.

5.4 *Streamlining external processes – BPR/redesign if needed*

Assuming that an enterprise has completed its internal housecleaning, restructuring, business process re-engineering and functional integration via ERP, the next step towards seamless integration over the supply chain is the integration with suppliers and customers.

Putting critical add-ons like e-procurement or CRM on top of the existing ERP system may require still further business process re-engineering related with critical processes, such as procurement approval cycles, order fulfilment or handling of customer complaints.

Pushmann and Alt (2005) clearly discuss the need for seamless integration with the existing ERP systems and talks about the need for 'e-procurement adaptors' which can allow integration with the backend systems. They emphasise the need to redesign the procurement processes for successful e-procurement activities and mention the following as main focuses of redesign in procurement practices:

- Reduction or elimination of authorisation stages.
- Regulation of exceptions.
- Elimination of paper, including automation of procurement stages.
- Integration of suppliers in the entire process chain.

Procurement and fulfilment are again suggested as the key processes within the supply chain, which require redesign and re-organisation in Muffato and Payaro (2004). The presence of an ERP system working before the initiation of an e-procurement system is also suggested in one of the Italian cases mentioned in the paper.

Bendoly and Kaefer (2004) report, after the analysis of 115 firms, that transactional efficiencies gained by B2B e-commerce technologies are greater in the presence of an ERP system and these effects are magnified when ERP implementation specifically precedes B2B e-commerce activities. Therefore, presence of an ERP system together with strategic sequencing and relative timing of the ERP and e-commerce implementations can impact the efficiencies of e-commerce applications.

In the light of these ideas, it is clear that providing efficient and effective interfaces with the existing ERP backbone together with reengineering of business processes related with the suppliers and customers are required for obtaining 'external' integration.

5.5 *Collaborative planning and joint management of key business processes*

Once the enterprise has reached the maturity of external integration with suppliers and customers on the web, the next step in the evolution is to be able to perform collaborative planning and joint management of the critical business processes. This involves forming strategic alliances and long-term partnerships with suppliers and customers, basing on mutual trust and win-win strategy.

Since 1995, new forms of collaboration are seen in information-sharing relations. The focus of these forms include not only a passive exchange of information between partners, but also a more proactive approach through common planning and synchronisation of activities and business processes (Skjoett-Laersen *et al.* 2003). In this regard, CFPR (collaborative forecasting, planning and replenishment) definition taken from ECR (Efficient Consumer Response Movement Organisation Europe, 2002) is mentioned as follows: 'A cross-industry initiative designed to improve the supplier/manufacturer/retailer relationship through co- managed planning processes and shared information' (Skjoett-Laersen *et al*. 2003). CFPR involves many players in an extended supply chain who provide information such as product usage and forecasts to all the players in that supply chain (Bendoly and Jacobs 2005).

Therefore, the concept of e-collaboration and collaborative planning over the web goes beyond simply e-buy and e-sell activities. The concept includes sharing of:

- Information.
- Decisions.
- Processes.
- Resources. (Wang 2005)

In such form of integration, the aim is to be able to obtain visibility/transparency and assure collaboration in the following functions:

- Planning.
- Forecasting.
- Design.
- Development.
- Management and service.

Joint problem solving and improvement for any of the above functions are essential for such collaboration; therefore, the concept is really broad and aimed at obtaining strategic partnerships. Benefits of e-collaboration are well-discussed in Wang (2005). To obtain these benefits, the basic types of information to be exchanged with suppliers and buyers are mentioned in Nguyen and Harrison (2004) as follows:

- Materials and inventory position.
- Product availability.
- Price information.
- Purchase orders and changes.
- Vendor receipt/acceptance.
- Invoice payments.
- Status reporting.

In Ho and Lin (2004), some of the major collaborative scenarios are given as follows:

- Product life cycle collaboration.
- Engineering project collaboration.
- Customer order and inventory collaboration.
- Distributor–re-seller collaboration.
- Supplier and procurement collaboration.
- Demand planning collaboration.
- Warehouse management and freight collaboration.

Besides standard operational planning, the need for long-term business planning, ability to perform feasibility checks for new orders or change requests across the network, mutual exception handling ability, multi-sourcing coordination and performance measurement are also needed within the scope of long term collaboration.

At advanced levels of collaboration scenarios, knowledge, experience and competencies are also shared in addition to basic business transactions and information (data related with demand, order planning, promotion and production).

Therefore, information visibility among partners, including shop floor status, design-related information and sales forecasts, is the key to such wide-scope collaboration. In this regard, willingness to share information is the basis of the partnership. Lack of mutual trust and unwillingness to share information among the partners appear to be the greatest obstacles in the way of e-collaboration. Skjoett-Larsen *et al*. (2003) support these ideas by referring to a previous survey and emphasises that issues of more organisational nature, like trust, lack of discipline and collaborative goals, are the real barriers towards CFPR initiatives.

To sum up, the ability to engage in collaborative planning and making joint decisions with both suppliers and customers are critical components of forming e-supply chain. Therefore, assuring basic external connectivity of sales and purchasing functions over the Internet is not sufficient to form e-supply chain. To be able to capture the real benefits of e-collaboration, much more than web-based exchange of operational transactional data is needed.

5.6 *Business intelligence and decision supports for all the partners*

In the previous section, it is clearly emphasised that more than simple e-buying or e-selling is needed to establish an e-supply chain. Since forming strategic business alliances and long term relations are in question, not only operational-level, transaction-based information sharing is involved. Exchange of information at tactical and strategic levels is needed as well. This definitely requires proper reporting, decision support and business intelligence mechanisms for each partner, backed up by their running ERP systems. Therefore, this means there is a clear need to support the ERP systems with reporting, data mining, data warehousing, decision support and business intelligence tools. Therefore, integrating such tools to obtain real-time managerial decision support becomes the real issue. Many ERP-based platforms, such as SAPs NetWeaver® BI (Business Intelligence), are currently in use towards this aim.

The ability to have multiple views of an enterprise in the form of 'info cubes' using OLAP (on-line analytical processing), 'drill-down' reporting capabilities to enable reporting at different levels of detail, exception broadcasting and adding BI reports to portals appear to be critical functions for business intelligence and decision support.

6. A look at technical knowledge and structures used for developing e-supply chain

6.1 *Basic technologies*

Over the past few decades, organisations have accumulated multiple generations of technology including monolithic, 2-tier, and 3-tier client/server architectures and now the industry is focusing on service-oriented architectures. Rogers (2003) mentions various key technologies for integration, including message-oriented access and transactional middleware, integration server software, information portals, application server deployment platforms, technology and application adaptors, workflow modelling and coding tools. Common use of XML and Java, portal-based, tiered architectures, and adaptor-based integration servers are the most frequently used technologies in this regard.

6.1.1 *Common use of XML and Java as software architecture*

In the literature, it is clear that many of today's integrated supply chain management systems use web technology as the supporting infrastructure. Lan (2005) mentions this by referencing the previous work by Dalton *et al*. (1998). Since web-based integration over the Internet requires a significant amount of electronic data interchange among different supply partners, use of common protocols and standards gain tremendous importance. Lan (2005) mentions that HTTP (HyperText Transfer Protocol), server-side Java, and XML are mostly used as software architecture and emphasises the need for some interfacing with old technologies, such as aging ERPs and legacy systems and by referring to Zieger (2001).

In Williamson *et al*. (2004), use of web development technologies such as XML and Java is again counted among standard phases to be passed to obtain inter-organisational integration. In Boyson *et al*. (2003), current use of different systems and standards is clearly emphasised.

Yen *et al*. (2002) talk about 'indispensability' of a common protocol to implement the connection of heterogeneous environments belonging to different partners within the supply chain. Some of the basic functionalities to be provided by an Internet-based information interchange are mentioned as follows:

- Transactional integrity.
- Connection stability.
- Authentication.
- Non-repudiation of messages.

Yen *et al*. (2002) emphasise a significant movement toward employing XML-based formats and technology and the search for standardisation in the EDI community. The fact that different rivals, such as IBM®, Microsoft®, Sun® and Oracle® all support core XML standards and major ERP software vendors such as SAP®, Peoplesoft® and Oracle® becoming 'XML-enabled' are clearly mentioned. In this paper, Microsoft's BizTalk, XML-based cross-platform application to enable B2B communication, is discussed as a case study.

In Xu (2005) the fact that 'large ERP vendors have incorporated XML syntax into their products' and Microsoft BizTalk Technology are emphasised. The SAP NetWeaver® platform is another example of ERP packages being XML enabled, as well as providing Java support on this platform via SAPs J2EE Engine of the SAP Web Application Server used for the Java and JSP components.

In Muffato and Payaro (2004), the XML web-based platform is counted among the standard implementation stages suggested. After the company passes the stages of using traditional standard communication tools, enterprise integration and use of web-based tools, a fourth step towards e-commerce applications is given as 'XML based platform'. The paper talks about four cases, Italian companies, using XML web-based platforms.

Besides Microsoft's BizTalk, other XML-based e-commerce frameworks such as RosettaNet and ebXML (e-business XML) are seen in the literature as initiatives of standardisation. In brief, these frameworks have the ability to support business processes definitions via XML schemas and to use standard messaging protocols such as HTTP (Dogac and Cingıl 2003).

To summarise, XML appears at the core of the standardisation and integration efforts to develop different integration platforms and frameworks.

6.1.2 *Portal-based, tiered architectures*

Portal-based, tiered architectures are frequently seen in the literature. Boyson *et al*. (2003) talk about a portal-based, three-tier e-supply chain integration solution by referring to a pilot project for US Department of Defense (DoD). It is mentioned that 'three-tier' architectures are developed to provide robust SCM systems. The integration system used in US Department of Defense (DoD) is again given by Lan (2005) as an example of three-tier architecture. In this structure:

- The first layer used corresponds to 'web portals' which provide access to suppliers and customers.
- The second layer is defined as a 'messaging infrastructure' which supports portals and provides the link to the underlying 'application layer', the third layer. Therefore, it acts like a bridge or central nervous system (Boyson *et al*. 2003) and becomes an intermediary infrastructure.
- The third layer is the 'application layer', being independent of any interface and containing all the business data and logic. This layer is defined to include ERP systems, SCM functionality, APS systems and decision support/business intelligence systems. Therefore, the application layer acts as a central repository for the data together with the business logic and all the core transactions are designed to happen here. It is clearly mentioned that data and business logic are stored independently in this third layer (Boyson *et al*. 2003, Lan 2005).

This three-tier architecture is shown in Figure 3.

In this three-layer architecture which is referred to in both Boyson *et al*. (2003) and Lan (2005), the following appear as the strengths of such portal-based, layered architectures:

- Web-based interface at both customer and supplier sides, provided by the web portals. This gives a starting point for accessing the web, assuring standardised interactions with the users, depending on their security clearance/authorisations. While assuring the secure access, this layer can be personalised, depending on the requirements and access classifications of the user.

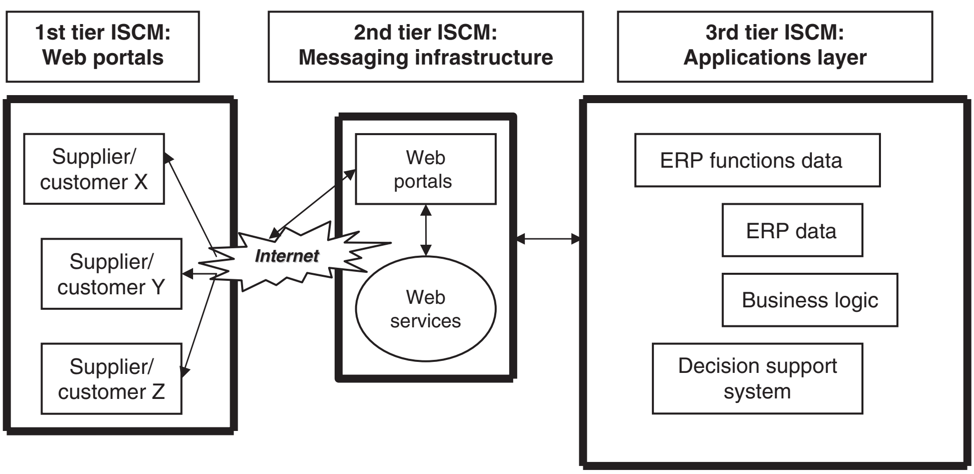

Figure 3. Three-tier architecture, as defined in Lan (2005).

- An intermediary infrastructure connecting the interface and the underlying application layer provides a clear separation of interface and the core business system. This gives us the opportunity of making 'plug and play' changes to the interface, without making any changes for the underlying business logic.
- Backbone application layer represents the 'integration' of the enterprise – both internal and external – since it includes legacy systems, all the ERP functionality, APS and collaborative planning options.

Such a layered architecture is totally in conformance with and supports the idea that ERP systems are the greatest enablers of e-supply chains, acting as a real backbone and a common database to support all the additional functions. These ideas are again supported by Xu *et al*. (2005) who suggest a web-based framework for manufacturing coordination. By discussing project 'Co-Operate', they suggest a system basing on automotive supply and semiconductor industries. The framework they suggested also uses ERP systems implemented – SAP's R/3 and APO (Advanced Planner and Optimiser) as the core and utilises XML.

6.1.3 *Adapter-based Integration servers*

Microsoft BizTalk Technology and Intersystems Ensemble can be given as examples of such technology. Chappell (2005) introduces 'Microsoft BizTalk Server 2006' technology as a general model for combining different systems into effective business processes. The technology is based on BizTalk Engine working internally with XML documents, uses adapter technology and standard web services such as SOAP (simple object access protocol), contains a graphical tool for defining the business process logic, has the schema definition and mapping capabilities basing on XSLT (extensible style sheet language transformations) and uses a message box implemented in SQL (structured query language).

Rogers (2003) mentions similar characteristics for InterSystems Ensemble, namely the use of adapter framework, persistent object and message engine, use of common web services, protocols and standards such as XML, SOAP, WSDL (web services definition language) and graphical business process modelling.

Basic advantages of the technology are briefly the use of common web services and standards, an adapter facility providing compatibility with various systems, plug-and-play capability, graphical support for process definitions and the ability to connect a number of heterogeneous systems.

6.1.4 *Other approaches*

In the literature, we can see other different approaches to supply chain integration.

Luo *et al*. (2001) define a graph-based hypernetwork formulation of e-supply chain and then formulate a fuzzy multi-objective optimisation problem. The optimised network is also simulated using discrete event simulation to analyze the stochastic behaviour of the network.

A previous work referenced in Lan (2005) is by von Mevius and Pibernik (2004), who propose a new approach to supply chain process management, based on a new high-level Petri-net called XML-net. XML-nets consist of supply chain data objects and physical supply chain object documents, supporting the exchange of intra- and inter-organisational data and offering superior supply chain process modelling capabilities.

Caputo *et al*. (2005) develop a framework for e-supply chains, identifying four sets of organisational structures on the basis of internal integration degree and decision making concentration degree.

Dotoli *et al*. (2006) define a generic IESC (integrated e-supply chain) basing on graph theory and develop single-criterion and multi-criterion optimisation models under structural constraint definitions. Besides cost and total lead time, their model objectives include energy and CO_2 emission, making their model sensitive to environment. They provide an Integer Linear programming problem solution to their model.

The difficulty of using such approaches is the integration of the proposed models and formulations with the backend ERP systems in an on-line, real-time manner. Assuring the connectivity of the model with day-to-day transactions of the ERP systems appear to be lacking, although these models are generic formulations with different optimisation criteria.

Agent-based approaches are also seen in the recent literature such as an agent-based decision support system suggested for an e-supply chain in Sadeh *et al*. (2003). For agent-based approaches, defining and standardising the agent behaviour across different platforms seem to be the greatest hurdle.

6.2 *Security and trust*

Since e-supply chain requires data sharing not only at a transactional level but also at tactical and strategic levels among supply chain partners, issues of security and privacy become vital. Clearly, what is needed is beyond transactional security. Assuring identification, authentication, authorisation, privacy, auditability and message integrity for more than one trading side, as well as dealing with intruders, malicious peers and security attacks, are major concerns. Main methods used in this regard are multiple digital signatures, different encryption methodologies and HTTP/SSL (hypertext transfer protocol/secure sockets layer). Among different XML-based frameworks mentioned in the previous subsections, RosettaNet and Microsoft BizTalk use digital signatures and HTTP/SSL, whereas ebXML framework uses extended SOAP. As such, current frameworks appear to rely on secure web services.

Besides addressing such technical concerns, establishing clear business policies, rules and agreements among partners in terms of confidentiality of the business processes and business documents are also critical. To maintain trust and collaboration among partners, such policies and agreements have vital importance. Therefore, security is one of the most critical issues to be considered, having both technical and managerial requirements.

7. A look at the challenges involved in developing e-supply chain

As can be seen from the scope and requirements of forming an e-supply chain, the implementation of an e-supply chain is a great challenge on the way to becoming a real e-collaborator. In Pant *et al*. (2003), the challenges involved in the implementation of a highly integrated supply chain are treated under the classification of 'internal' and 'external' challenges. Many concerns such as security, change in business processes, presence of weaker supply chain partners, organisational resistance, are mentioned as challenges while trying to achieve both internal and external integration.

The challenges involved in e-supply chain formation can also be classified as 'technical' and 'managerial/organisational' challenges. Assuring the continuity and maintenance of the system is critical throughout the lifetime of the system posing still further challenges.

7.1 *Technical challenges*

The technical infrastructure of an e-supply chain is inherently much more complicated than the information infrastructure of a single enterprise, as more than one partner is involved. Therefore, the necessary sophisticated infrastructure should be provided which can:

- Support on-line, real-time connectivity and visibility among heterogeneous information systems of more than one party, including their legacy systems.
- Handle network-based requirements and security issues, being a critical issue for especially highly sensitive data.
- Guarantee necessary business intelligence/decision support to enable collaborative planning.
- Guarantee training and all related technical skills to install and maintain such an infrastructure.

Therefore, combining possibly inconsistent/incompatible information systems of different parties in a secure, reliable and efficient manner, together with sufficient decision support capabilities, is clearly a technical challenge. These challenges, including the need to have a highly sophisticated technology infrastructure, legacy system considerations and security needs are clearly mentioned in Pant *et al*. (2003). These are the concerns for the interest of different audience in the technical domain, including solution developers and people from networking and security domain.

7.2 *Managerial/organisational challenges*

Besides all these technical challenges, there are various managerial/organisational challenges involved in forming an e-supply chain, which are of interest for both end users and managerial people. While establishing an e-supply chain, a managerial and organisational approach should be followed that can:

- Guarantee managerial vision, support and commitment (not only from one partner but from all the partners).
- Utilise project management techniques to enable proper planning and project management.
- Overcome internal resistance within the organisations of each partner.
- Overcome external resistance and assure mutual trust among all external partners.
- Guarantee compatibility of strategies, objectives and goals among supply chain partners.
- Provide sufficient financial, technical and human resources.

Since external integration of an enterprise is involved in forming an e-supply chain, managerial support, commitment, proper planning, coordination and sufficient resources (financial, technical, human) are needed from more than one partner. Creating and maintaining mutual trust, eagerness to exchange information, willingness to cooperate and collaborate on various business functions are critical challenges which must be met by all the partners in an e-supply chain. In Pant *et al*. (2003), organisational resistance, commitment, time, availability and mutual trust issues are emphasised as challenges, supporting all these ideas.

7.3 *Assuring the continuity and maintenance of the system*

Assuming a successful implementation of e-supply chain, assuring the continuity and adaptability of the e-supply chain to changing conditions is still a further challenge. Monitoring, performance measurement, control and early warning mechanisms are needed to be developed and agreed upon among different partners. Common performance indicator definitions and measurement methods, consistent understanding and evaluation of these metrics, agreed-upon review frequencies, compatible early-warning systems and consistent actions to warnings are vital for gaining strategic success and survival of all the partners.

To sum up, the challenges involved in implementing integrated e-supply chains are bigger than the problems faced by an organisation trying to adopt internal systems (like ERP) or external systems (like EDI) (Pant *et al.* 2003). Therefore, any technical and managerial/organisational challenge valid for other types of implementations is amplified in e-integration. This is true because of the presence of multiple, inconsistent technical infrastructures, inconsistent or even conflicting managerial approaches, possibly different corporate cultures and resource bases.

8. Conclusion and future research

In this study, strong support is found for the following in recent literature:

- The need to consider internal integration prior to efforts of external integration with suppliers and customers, keeping in mind the legacy systems.
- The need and importance for business process re-engineering for both internal and external processes.
- Importance of handling ERP implementations prior to web-based integration efforts towards forming an e-supply chain.
- The need to take previously implemented ERP systems as the core for integration efforts of various ‘bolt-on’ applications, such as CRM, APS towards forming an e-supply chain.
- Widespread use of XML and Java in various integration efforts.
- Importance of layered, portal based infrastructures.

As companies evolve in their connectivity and integration efforts, the ability of supply chain partners to engage in collaborative planning and joint management of critical business activities become the key to efficiency, effectiveness and success of the overall supply chain. Web-based exchange of operational data at a transactional level is clearly not sufficient for this aim. The need for web-enabled, on-line, real-time support for managerial decision making to handle ‘business intelligence’ needs, with proper authentication and authorisation mechanisms is evident.

The challenges involved in forming an e-supply chain and web-based joint strategic management are clearly much more profound than the challenges of an ERP implementation. The majority of the challenges are still organisational and managerial, with amplified technical challenges such as network connectivity of heterogeneous systems and web-based security. In today’s digital economy, success will follow for those organisations which can handle all these challenges towards better web-based integration.

Despite the frequent use of XML and Java, lack of standard infrastructures and frameworks appears to be continuing. Industry is still in search of common standards, protocols and frameworks to integrate different cross-platform applications over the Internet to provide seamless integration among supply chain partners. Future research in this regard lies in standardisation efforts and development of frameworks.

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