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Information systems in supply chain integration and management

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Abstract

Supply chain management (SCM) is the 21st century global operations strategy for achieving organizational competitiveness. Companies are attempting to find ways to improve their flexibility and responsiveness and in turn competitiveness by changing their operations strategy, methods and technologies that include the implementation of SCM paradigm and information technology (IT). However, a thorough and critical review of literature is yet to be carried out with the objective of bringing out pertinent factors and useful insights into the role and implications of IT in SCM. In this paper, the literature available on IT in SCM have been classified using suitable criteria and then critically reviewed to develop a framework for studying the applications of IT in SCM. Based on this review and analysis, recommendations have been made regarding the application of IT in SCM and some future research directions are indicated.

Keywords: Information technology; Supply chain management; Literature review; Framework

1. Introduction

Nowadays, companies are in the race for improving their organizational competitiveness in order to compete in the 21st century global market. This market is electronically connected and dynamic in nature. Therefore, companies are trying to improve their agility level with the objective of being flexible and responsive to meet the changing market requirements. In an effort to achieve this, many companies have decentralized their value-adding activities by outsourcing and developing virtual enterprise (VE). All these highlight the importance of information technology (IT) in integrating suppliers/partnering firms in virtual enterprise and supply chain. Supply chain management (SCM) is an approach that has evolved out of the integration of these considerations. SCM is defined as the integration of key business processes from end user through original suppliers that provides products, services, and information and hence add value for customers and other stakeholders (Lambert et al., 1998).

SCM is an increasingly applied operations paradigm for enhancing overall organizational

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competitiveness. A recent survey of more than 300 supply chain-related executives found that 92% of those surveyed were planning to implement one or more supply chain initiatives in 1999 (Bradley, 1999). SCM is based on the integration of all activities that add value to customers starting from product design to delivery. According to Simchi-Levi et al. (2000), SCM is a set of approaches utilized to effectively integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize systemwide cost while satisfying service level requirements.

There are numerous articles on the strategies, techniques and technologies for the design and development of SCM. Also, several literature-survey papers which include taxonomy of SCM, and modelling and analysis of SCM (e.g. Tan, 2001). However, there is a very few literature survey article that deals with IT in SCM. However, it is impossible to achieve an effective supply chain without IT. Since suppliers are located all over the world, it is essential to integrate the activities both inside and outside of an organization. This requires an integrated information system (IS) for sharing information on various value-adding activities along the supply chain. IT is like a nerve system for SCM. There are many articles on IT in supply chain. Most of the literature discusses only the implications of one or two aspects of supply chain, for example, strategies, tools and techniques, but not in an entirety. However, a comprehensive survey of IT in SCM will be useful to identify the critical success factors of IT for an integrated supply chain. Unfortunately, design and implementation of IT system for an effective SCM have not received adequate attention from both researchers and practitioners, in particular, business to business (B2B) e-commerce (EC) and SCM. There are lots of debates around the applications of IT in SCM concerning business to business e-commerce model, matching to business model, etc. Considering the importance of IT in achieving effective SCM, an attempt has been made in this paper to review the literature on IT in SCM based on suitable criteria. The main objective here is to identify the major issues surrounding the application of IT in SCM, using suitable classification scheme and develop a framework for IT applications in SCM. Also, some future research directions are indicated for developing IT embedded SCM system.

The organization of the paper follows as Section 2 discusses the role of IT in SCM. The details of the research methodology are presented in Section 3. Section 4 presents the classification scheme used for reviewing the selected literature available on IT in SCM. A brief review of the literature is presented in Section 5. In Section 6, a framework has been developed for the application of IT in SCM. Finally, conclusions are presented in Section 7.

2. Information technology in supply chain management

Recently the concepts of supply chain design and management have become a popular operations paradigm. This has intensified with the development of information and communication technologies (ICT) that include electronic data interchange (EDI), the Internet and World Wide Web (WWW) to overcome the ever-increasing complexity of the systems driving buyer–supplier relationships. The complexity of SCM has also forced companies to go for online communication systems. For example, the Internet increases the richness of communications through greater interactivity between the firm and the customer (Watson et al., 1998). Graham and Hardaker (2000) highlight the role of the Internet in building commercially viable supply chains in order to meet the challenges of virtual enterprises. Philip and Pedersen (1997) attempt to study the ways in which the business community harnesses EDI with the help of a literature survey based on the application.

Armstrong and Hagel (1996) argue that there is beginning of an evolution in supply chain towards online business communities. For example, General Electric's trading process network is an online business community that allows the company to transact about $1 billion dollar worth of business with their suppliers located all over the globe. Big three auto makers in the US are in the process of

launching the automotive network exchange (ANX) to further understand the impending effects of electronic business communities. ANX will establish a standard method for parts suppliers to communicate with and obtain order information from the auto manufacturers (Graham and Hardaker, 2000).

Supply chain management emphasizes the overall and long-term benefit of all parties on the chain through co-operation and information sharing. This signifies the importance of communication and the application of IT in SCM. This is largely caused by variability of ordering (Yu et al., 2001). Information sharing between members of a supply chain using EDI technology should be increased to reduce uncertainty and enhance shipment performance of suppliers and greatly improve the performance of the supply chain system (Srinivasan et al., 1994).

Companies need to invest large amount of money for redesigning internal organizational and technical processes, changing traditional and fundamental product distribution channels and customer service procedure and training staff to achieve IT-enabled supply chain (Motwani et al., 2000). The following are some of the problems often cited in the literature both by the researchers and practitioners when developing an IT-integrated SCM: lack of integration between IT and business model, lack of proper strategic planning, poor IT infrastructure, insufficient application of IT in virtual enterprise, and inadequate implementation knowledge of IT in SCM. There is no comprehensive framework available on the application of IT for achieving an effective SCM. Considering the importance of such a framework, an attempt has been made in this paper to develop such a framework based on a more systemic literature review.

3. Research methodology

The research methodology employed for developing the framework for the successful application of IT in SCM is the literature survey. We have collected literature primary through journals that are in the areas of operations management, supply chain, operations research and information systems. For rigorousness, we excluded dissertations, textbooks, and unpublished working papers, and conference proceedings papers. The list of journals and the number of articles from each of those journals are presented in Table 1.

In addition to the classification of the literature on IT in SCM, the tools used to model and analyze various IT-enabled SCM environments also presented. This would be useful to researchers who are interested in modelling and analysis of various decision-making environments with reference to IT in SCM. The literature search has been conducted with the help of e-journal's search engines available in The Hong Kong Polytechnic University library. These include access to the journals published by a numerous publishers in particular Elsevier, Emerald, and Taylor & Francis.

The literature search was aimed at primarily helping researchers and practitioners in implementing a successful IT system for achieving an effective SCM. With this in mind, we looked at the literature that deals with IT-enabled SCM.

4. Classification of the literature on IT in SCM

In this section, a classification scheme has been proposed to review the literature available on IT integrated SCM, based on certain major critical areas for the successful development of IT-enabled SCM. This classification has the objective of bringing out pertinent factors that would support practitioners in their efforts to successfully achieving an IT-enabled SCM. This literature survey is aimed to identify the critical success factors for the applications of IT in SCM, integration of partners/suppliers and IT, B2B e-commerce in SCM, and for successful implementation of IT in a supply chain. Also, an attempt also has been made to offer a framework for the development of IT-enabled SCM and suggest some future research directions. The classification is based on the implications of strategic decisions, potential areas of IT applications in SCM, and the level of interaction between various constituents in developing an effective supply chain. For example, virtual enterprise and SCM are inseparable objectives. Therefore, the role

Table 1
The articles resources—journals

Title of the journal	Number of articles
Academy of Management Journal	1
Assembly Automation	1
Business Process Management Journal	3
California Management Review	1
European Journal of Operational Research	1
European Journal of Purchasing & Supply Management	2
Harvard Business Review	3
Human Systems Management	1
IBM Systems Journal	1
IIE Solutions	1
Industrial and Commercial Training	1
Industrial Management & Data Systems	4
Industrial Marketing Research	1
Information & Management	1
Information and Software Technology	1
Information Management & Computer Security	2
Integrated Manufacturing Systems	2
Interfaces	1
International Journal of Agile Management Systems	1
International Journal of Information Management	4
International Journal of Logistics Management	2
International Journal of Operations & Production Management	7
International Journal of Physical Distribution and Logistics Management	11
International Journal of Production Economics	4
International Journal of Quality & Reliability Management	1
International Journal of Retail & Distribution Management	2
International Journal of Service Industry Management	1
International Marketing Review	1
Internet Research: Electronic Networking Applications and Policy	1
Journal of Business Logistics	3
Journal of Electronic Commerce Research	1
Journal of Information Technology	1
Journal of Knowledge Management	1
Journal of Management Information Systems	1
Journal of Organizational Change	1
Journal of Strategic Information Systems	2
Journal of Systems and Software	1
Library Consortium Management: An International Journal	1
Logistics Information Management	13
Logistics Management and Distribution Report	1
Management Decision	1
Management Science	2
MIS Quarterly	1
Production and Inventory Management Journal	1
Project Management	1
Purchasing	2
Robotics and Computer Integrated Manufacturing	1
Sloan Management Review	1
Strategy & Leadership	1
Supply Chain Management Review	2
Supply Chain Management: An International Journal	10
Team Performance Management: An International Journal	1
Work Study	1

and the development of virtual enterprise have been brought up into while studying the applications of IT in SCM. Similarly, e-commerce is one of the key enabling technologies for achieving an effective SCM and knowledge management (KM) in essential in Internet-enabled SCM. Nevertheless, implementation issues have been significant in achieving the full potential of IT in SCM.

As indicated above, the classification scheme is based on the major components of IT-enabled SCM. The selected articles are classified into five major broad categories focusing on developing an IT-enabled SCM:

(a) *Strategic planning for IT in SCM*

The strategic planning is a critical task especially for IT-enabled SCM. It has long-term implications on the performance of IT in SCM systems.

(b) *Virtual enterprise and SCM*

Virtual enterprise is based on outsourcing concept to take advantage of the core competencies with the objective of being flexible and responsive to changing market requirements. Companies integrate various links of the supply chain and their supporting information systems that are driven by the need to streamline operations. The relationships of VE and the Internet have brought SCM to the attention of top management.

(c) *E-commerce and SCM*

With the development of Internet based technologies, integration of e-commerce with SCM systems is becoming a necessity. It can support various activities along the supply chain. B2B e-commerce has tremendous influence on integrating partners in an organization to achieve an effective SCM.

(d) *Infrastructure for IT in SCM*

Companies suffer without having sufficient knowledge on what type of IT infrastructure or systems required for their business model to achieve an IT-enabled supply chain. The infrastructure includes the hardware and software and the nature and type of systems required for IT system in a supply chain environment.

(e) *Knowledge and IT management in SCM*

Since we are operating in information and automation intensive world, there is a need for knowledge workers to contribute to the value-adding activities in advanced organization. Knowledge and IT management requires a systemic approach or framework for educating and training workers in teamwork and be innovative. Management of technology requires planning, developing and implementation decisions based on the characteristics of business processes and organizational objectives.

(f) *Implementation of IT in SCM*

Implementation of IT in SCM requires a project management approach with the right team for the planning and implementation of IT projects. Top management support is essential in order to provide moral support as well as the financial and technical support for the implementation of IT for achieving SCM.

With an effort to be current on the research field, we only considered research articles published from 1994 to date. This could be substantiated by the timing of the emergence of SCM and IT concepts. We have looked at the other review articles on SCM, but none of them deals exclusively with a comprehensive review and analysis of IT in SCM. The details of the major classification scheme and articles that come under each such classification is presented in Table 2.

5. Review of previous research on IT in SCM

In this section, the literature available (through journal articles mostly) on IT in SCM has been reviewed for its application and development based on the classification scheme discussed in the previous section (Table 3).

5.1. Strategic planning for IT in SCM

Companies are now focusing on the strategic planning with the objective of developing long-term plans and changes to their organization and in turn to improve their competitiveness. Planning for strategies require top management involvement taking into account both external and internal factors to an organization. Strategic planning of IT should support the long-term objectives and goals of SCM both in terms of flexibility and responsiveness to changing market requirements.

Table 2
Classification of the literature available on IT in SCM

Classification criteria	References
Strategic planning for IT in SCM	Rockhart and Scott Morton (1984), Porter and Millar (1985), Gallupe et al. (1992), Henderson and Venkataraman (1993), Rogerson and Fidler (1994), Webster (1995), Sambasivarao and Deshmukh (1995), Fletcher and Wright (1996), Ho (1996), Maloni and Benton (1997), Williams (1997), Brown and Eisenhardt (1998), Cerpa and Verner (1998), Daniels (1998), King (1978), Bradley (1999), Teo and Ang (1999), Kardaras and Karakostas (1999), Ang et al. (2000), Zimmerman (2000), Christiaanse and Kumar (2000), Talluri (2000), Andersen (2001), van Hooft and Stegwee (2001)
VE and SCM	Davidow and Malone (1992), Webster (1995), Mariotti (1996), Voss (1996), Skyrme (1996), Lewis and Talalayevsky (1997), Clements (1997), Clarke (1998), Kornelius and Wamelink (1998), Browne and Zhang (1999), Bal and Gundry (1999), Naylor et al. (1999), Black and Edwards (2000), Boardman and Clegg (2001), Bhatt and Emdad (2001), van Hoek (2001), Sarkis and Sundararaj (2002), Turowski (2002)
E-commerce and SCM	Emmelhainz (1990), Cooper (1994), Chiu (1995), Carbone (1995), Bowersox and Daugherty (1995), Benjamin and Wigand (1995), Kalakota and Whinston (1996), Murray (1996), Christopher (1997), Roberts and Mackay (1998), Frook (1998), Feraud (1998), Min and Galle (1999), Walton and Gupta (1999), Ball and Wright (2000), Reynolds (2000), Doherty (2000), Elliman and Orange (2000), Emiliani (2000), Fontanella (2000), Hackney et al. (2000), Kaplan and Sawhney (2000), Lancioni et al. (2000), Marshall and McKay (2000), McIvor et al. (2000), Overby and Min (2001), Wang (2000), Salcedo and Grackin (2000), Croom (2001), Damen (2001), Emiliani and Stec (2001), Kehoe and Boughton (2001), Murillo (2001), Overby and Min (2001), van Hoek and Chong (2001), Alshawi (2001)
Infrastructure for IT in SCM	Klouwenberg et al. (1995), Mason-Jones and Towill (1997), Mukherji and Mukherji (1998), Walsh and Koumpis (1998), Watson et al. (1998), Haeckel (1999), Ranchhod and Gurau (1999), Al-Mashari and Zairi (2000), Attaran (2001), Huang and Mak (2000), Jayaram et al. (2000), Lau and Lee (2000), Perry and Sohal (2000), Cheng et al. (2001), Humphreys et al. (2001), Au and Ho (2002), Sarkis and Sundararaj (2002), Sharma and Gupta (2002), Yamaya et al. (2002)
Knowledge and IT Management in SCM	McCampbell et al. (1999), Angeles and Nath (2000), Motwani et al. (2000), Talluri (2000), Walsh et al. (2000), Boubekri (2001), Nah et al. (2001), Tracey and Smith-Doerflein (2001), van Hoek (2001), Warkentin et al. (2001), Jutla et al. (2002), Spekman et al. (2002)
Implementation of IT in SCM	Cooper and Zmud (1990), Ho (1996), Scott (1996), Hicks (1997), Mullin (1997), Calza and Passaro (1997), Williams et al. (1998), Williford and Chang (1999), Angeles and Nath (2000), Lauer (2000), Al-Mashari and Zairi (2000), McIvor et al. (2000), Pawar and Driva (2000), Kuruppuarachchi et al. (2002)

For example, IT will facilitate quick partnership formation by making available the right information and hence developing a virtual enterprise. Organizational restructuring may be required if a company decides to go for an enterprise resource planning (ERP) systems such as SAP, Oracle, Peoplesoft, and BAAN with the objective establishing an effective supply chain. There are also other potential implications such as investment in IT and reengineering business process, market orientation, technology position and employee relations, and workforce characteristics. The issue of societal implications and knowledge management should be given due consideration in developing strategic planning for IT in SCM. However, it is essential to prioritize strategic dimensions that influence IT in SCM taking into account an individual organizational structure.

Cerpa and Verner (1998) present a longitudinal study of the information systems strategic planning

Table 3
Summary of references under detailed classification scheme of the literature on IT in SCM

Classification	Sub-classification	References
Strategic planning of IT in SCM	Marketing reasons of IT in SCM	Rockhart and Scott Morton (1984), Webster (1995), Ho (1996), King (1978)
	Economic reasons	Porter and Millar (1985), Williams (1997), Talluri (2000)
	Organizational	Gallupe et al. (1992), Henderson and Venkataraman (1993), Rogerson and Fidler (1994), Maloni and Benton (1997), Brown and Eisenhardt (1998), Daniels (1998), Lockamy and Smith (1998), Teo and Ang (1999), Ang et al. (2000), Werbach (2000), Andersen (2001)
	Technological	Christiaanse and Kumar (2000), van Hooft and Stegwee (2001)
Virtual enterprise in SCM	Partnership	Webster (1995), Skyrme (1996), Voss (1996), Lewis and Talalayevsky (1997), Zimmerman (2000)
	Virtual reality and supply chain	Benjamin and Wigand (1995), Clarke (1998), Bal and Gundry (1999), Boardman and Clegg (2001), Bhatt and Emdad (2001), Sarkis and Sundararaj (2002)
	Virtual enterprise and IT	Webster (1995), Clements (1997), Naylor et al. (1999), Black and Edwards (2000), van Hoek (2001), Turowski (2002)
E-commerce and SCM	Purchasing	Emmelhainz (1990), Murray (1996), Carbone (1995), Min and Galle (1999), Elliman and Orange (2000), Emiliani (2000), McIvor et al. (2000), Wang (2000), Croom (2001)
	B2B e-commerce and supply chain	Benjamin and Wigand (1995), Frook (1998), Roberts and Mackay (1998), Walton and Gupta (1999), Ball and Wright (2000), Emiliani (2000), Hackney et al. (2000), Kaplan and Sawhney (2000), Marshall and McKay (2000), Salcedo and Grackin (2000), Overby and Min (2001), Warkentin et al. (2000), Kehoe and Boughton (2001), Emiliani and Stec (2001), Murillo (2001)
	Logistics	Cooper (1994), Bowersox and Daugherty (1995), Chiu (1995), Verwijmeren et al. (1996), Christopher (1997), Feraud (1998), Wilson and Clarke (1998), Ranchhod and Gurau (1999), Emiliani (2000), van Hoek and Chong (2001), Damen (2001), Alshawi (2001), Tollington and Wachter (2001)
Infrastructure for IT in SCM	Organizational	Klouwenberg et al. (1995), Mukherji and Mukherji (1998), Watson et al. (1998), Zsidism et al. (2000), Attaran (2001), Cheng et al. (2001), Humphreys et al. (2001)
	Technological	Al-Mashari and Zairi (2000), Huang and Mak (2000), Jayaram et al. (2000), Lau and Lee (2000), Perry and Sohal (2000) Au and Ho (2002), Sharma and Gupta (2002), Yamaya et al. (2002)
Knowledge and IT management in SCM	Technology management	Dos Santos (1991), Angeles and Nath (2000), Motwani et al. (2000), Talluri (2000), Walsh et al. (2000), Boubekri (2001), Nah et al. (2001), Warkentin et al. (2001), Jutla et al. (2002), Spekman et al. (2002)
	Education and training	McCampbell et al. (1999), Tracey and Smith-Doerflein (2001), van Hoek (2001)
Implementation of IT in SCM	Organizational	Ho (1996), McIvor et al. (2000)
	Methodological	Cooper and Zmud (1990), Scott (1996), Calza and Passaro (1997), Hicks (1997), Mullin (1997), Williams et al. (1998), Al-Mashari and Zairi (2000), Angeles and Nath (2000), Lauer (2000), Pawar and Driva (2000)
	Human resource	Calza and Passaro (1997), Williford and Chang (1999)

process (ISSP) within a large Australian organization. They discuss ISSP with regard to its strategic relevance, factors affecting IS strategic planning, key issues in ISSP, the effects of infusion and diffusion levels, together with the effect of IS maturity on ISSP. However, the effect of operational impact

has not been given due consideration including the application of ERP.

Fletcher and Wright (1996) report a study into the relationship between strategic use of information technology in financial service organizations and the strategic context within which such use is made. They found a good degree of integration of marketing and IT groupings with the strategic planning process, but document a high degree of strategic ambiguity and lack of strategic time frame for such investment decisions. The major reason for strategic ambiguity and time frame for investments in IT is the lack of understanding of the business processes and justification for a suitable IT system for SCM. Kardaras and Karakostas (1999) suggest the use of fuzzy cognitive maps as an alternative approach to existing strategic information systems planning models. This is a useful tool to facilitate creativity and synergy; to develop consensus and win commitment of those on whose actions the organization's future defends. However, such tools should be user friendly and have significant commitment from the management while implementing the recommendations made using the tools.

Manufacturing information system's strategic role includes minimizing manufacturing's negative potential, achieve parity with competitors, provide credible support to the business strategy and pursue a manufacturing-based competitive advantage.

5.1.1. Marketing reasons of IT in SCM

To compete in a new market, organizations need to be capable of reconfiguring its resources to meet the changing requirements. This requires organizations to have an effective supply chain or physically distributed enterprises. Ho (1996) highlights three major roles of IT as administrative, operational and competitive (King, 1978; Rockhart and Scott Morton, 1984). However, there is a need to address the alignment between operations strategy and IT strategy. A strategic alignment model for a manufacturing information system that specifically addresses the requirements of leveraging the emerging developments in information technologies would be useful. According to Ho (1996), firms are now capable to designing and developing IT platforms as competitive weapons at a fraction of the cost that prevailed only a few years ago. The second issue is the increased connectivity capabilities over time.

Webster (1995) draws upon the insights developed within the sociology of technology, in which innovation is not simply a technical-rational process of "solving problems"; it also involves economic and political processes in articulating interests, building alliances and struggling over outcomes. This includes strategic interests of powerful corporate players and the struggles of these players for domination in the marketplace.

5.1.2. Economic reasons

The market is the driving force for any changes in an organization. Market factors such as customer requirements, competitors and price force organizations the way they manage their operations. For example, companies select to for IT-enabled SCM in order for companies to compete in a networked economy wherein you have to compete in a global market by multiple competitive performance objectives such as price, quality, flexibility, responsiveness and dependability. The economic reasons here is the cost reason. Though flexibility and responsiveness are important in order to compete in a global and networked market, the cost still plays an important role in being competitive. Obviously, flexibility and responsiveness are interconnected with cost. Many companies choose cost reduction as a competitive performance objective. In order to reduce the cost of production, companies have implemented the concept of SCM with a view to eliminate non-value-adding activities. IT helps to improve the accurate information flow and in turn accurate decisions to support the business process in an effort to meet the changing market requirements. Availability of resources locally make some companies to opt for global outsourcing and this again demands an IT-enabled SCM with a view to overcome lack of resources.

Adaptability and previous experience of both data processing management and the user managers will be crucial for the planning and implementation of new systems (Williams, 1997). However, the top management support and due investment in training and education are essential

for successful application of IT in SCM. Talluri (2000) presented a multi-objective model that incorporates both tangibles and intangibles criteria for evaluation of IT/information systems systems for SCM. His model integrates four critical performance measures, viz., flexibility, quality, time and cost. The focus on economic reasons have been misunderstood and misread due to lack of models and framework for decision making on IT in SCM.

5.1.3. Organizational

Strategic planning of IT in SCM includes organizational issues such as organizational structure, awareness of top management, business processes, strategic alliances, and information technology that influence the overall performance of IT-enabled SCM. Considering the organizations business and top level strategies, suitable information systems should be selected with a view to support the application of IT and in turn to develop an effective supply chain. Since the current enterprise structure is complex in nature and therefore, there is a need for an effective IT system to manage the system in a more productive manner.

Rogerson and Fidler (1994) presented a framework for classifying strategic information system planning methodologies involves on two dimensions; structural complexity and application complexity. But the issue of cultural complexity has been left out! Ang et al. (2000) develop a framework for measuring the impact of IT on quality management. Total quality management (TQM) requires teamwork, collaborative supported work, training and education in value-adding processes and the application of multimedia will enhance the communication and hence a good decision support system that is flexible and responsive. This is an interesting article wherein the author integrates the issues of TQM with IT in SCM.

The value chain, that is the chain of activities that creates customer value are interrelated (Daniels, 1998). Business strategies require the organization to change. IS can be a supportive facilitator of change—extending and enhancing organization choice and improving the quality of decision making and supporter of innovation. Henderson and Venkataraman (1993) proposed a comprehensive framework of IS strategic alignment incorporating four fundamental domain of strategic choice: business strategy, IT strategy, organizational infrastructure and processes, and IT infrastructure and processes. Nevertheless, the strategic human aspects have been ignored.

The emergence of new network technologies and expansion of the Internet can improve an organization's internal and external communication capabilities. Lower information processing costs make co-ordination and mutual adjustment processes more efficient, and therefore improve organizational performance (Andersen, 2001). It also supports decentralized and less hierarchical organizational structure. Electronic communication is less formal, reduces organizational barriers. Electronic communication enhances innovation particularly in large dispersed groups (Gallupe et al., 1992). However, there is a need to standardize the information flow and access control to information along the supply chain. Teo and Ang (1999) found that management commitment to the strategic use of IT/IS management knowledge about business, and top management confidence in the IS department are the top three critical success factors.

Organizational design for IT-enabled SCM is rather flexible as it takes the structure depending upon the business nature and strategic alliances including the characteristics of the market and business processes. For complex system organizational forms, Brown and Eisenhardt (1998) argue that (1) organizational forms that have neither too little nor too much structure; and (2) organizations that have an adaptive culture with semi-structures use real-time communications. It is an interesting finding. However, standardization of business processes and IT systems facilitate an effective and protected access information in a supply chain.

5.1.4. Technological

Strategic planning involves decisions that affect the long-term performance of an organization. For example, lack of IT in an organization can make the organization obsolete and not to qualify being as one of the partners in a virtual enterprise. Since

the market characteristics have changed, it would be difficult to survive in a global market without an IT-enabled SCM. IT helps to improve collaborative-supported work using different automation that includes computer-aided design/computer-aided manufacturing (CAD/CAM) and CIM. For example, IT-enabled SCM facilitate effective technology transfer between partners in a network of firms.

Using e-business technologies, and hence ultimately providing a fully integrated e-business process can integrate activities along the value chain. Integration of the physical processes and e-businesses applications is essential to achieve an effective SCM (van Hooft and Stegwee, 2001). van Hooft and Stegwee (2001) argue that a fundamental approach to setting up an e-business initiative is needed to fully utilize the capabilities of the Internet technology in a specific business setting. They proposed method to help clarify a strategic e-business vision and to solicit management commitment to change and on new business opportunities. This also takes into the unique possibilities of an organization's IT architecture, this further advancing the value of past investments in IT.

The widespread availability of highly flexible, functional and inexpensive information and communication technologies provides us with opportunities for a radical redesign of supply chains. Christiaanse and Kumar (2000) develop general principles for ICT-enabled redesign of supply chains. Redesign of supply chain should include a rethinking of the governance structures, a choice of the supply chain actors, redesign of the supply chain structure (sequence of activities in the chain), and redesign of information communication and co-ordination structures.

Strategic consideration of IT-enabled SCM is important since companies are interested in long-term survival and success with the objective of meeting changing market requirements. Global market and competitiveness center around global outsourcing and partnership and these signify the ICT-integrated SCM. The risk of not having IT-enabled SCM is enormous both in terms of survival and productivity of an organization. For example, competitor action influences the strategies of each other whether in terms of strategies or technologies. Therefore, strategic planning of IT-enabled SCM is important in the development of a supply chain.

5.2. Virtual enterprise in SCM

Virtual enterprise (VE)/virtual organization (VO) is based on developing a network of collaborative firms with necessary core competencies for reaching the market on time with right products. Developing a network of firms requires a communication system to achieve a co-operative supported work. This could be achieved by utilizing various telecommunication technologies. That is IT is so important in developing and operating a VE/VO. There are numerous papers that deal with VE and IT. This includes the strategic planning of IT in VE development, infrastructure and implementation issues of IT in VE/VO.

Virtual enterprise is a network of independent companies, often former competitors, who come together quickly to exploit fast-changing opportunities. The business partners are integrated using information and communication technology. Virtual Corporation is the industrial strategy for structuring and revitalizing the corporation for the 21st century (Davidow and Malone, 1992). Lean production and agile manufacturing mainly focus on intra-enterprise performance, while also recognizing the necessity and importance of partnerships with supplies and customers (Mariotti, 1996). The extended enterprise and the virtual enterprise can be seen in the context of enterprise partnerships, designed to facilitate co-operation and integration across the value chain (Browne and Zhang, 1999). Some of the key factors in virtual enterprise development are IT-enabled SCM, partnership, virtual enterprise and supply chain, and virtual enterprise and IT. The literature available on virtual enterprise for SCM has been reviewed using these factors with the objective of identifying critical success factors for the development of VE.

5.2.1. Partnership

Growth of networking, both human and technological creates a virtual world with virtual

products and services, virtual workplaces and virtual organizations (Skyrme, 1996). The virtual products and services are produced, delivered and sold through electronic networks. Lewis and Talalayevsky (1997) argue that the managerial and cultural aspects of strategic partnerships in logistics involving such issues as "openness to innovation" and "trust" are just as critical as IT.

Webster (1995) deals with the design and use of interorganizational information reflect the strategic interests of powerful corporate players and the struggles of these players for domination in the marketplace. He draws upon the insights developed within the sociology of technology, in which innovation is not simply a technical-rational process of "solving problems"; it also involves economic and political processes in articulating interests, building alliances and struggling over outcomes.

5.2.2. Virtual teams and supply chain

The design, manufacture and delivery of a product require ever-higher levels of knowledge and expertise within the supply chain. Virtual teaming is the most appropriate mechanism to examine the relationship between all parties along the value chain, created across a distributed supply chain, with members separated geographically. In principle, virtual teaming could allow joint commitment, feelings of mutuality, trust and creativity and rapid decision making to operate within a supply chain. Virtual team needs to be built by concentrating on process, teaming and technology factors. However, experience from other IT-based initiatives is that technology will be concentrated onto exclusion of other factors (Bal and Gundry, 1999).

Boardman and Clegg (2001) present a framework for structuring and synchronizing phases and stage-gates within the extended enterprise, and a new simulation tool that will provide a synthetic distributed hypermedia network. An increasing number of manufacturers adopt the virtual enterprise metaphor, inter-organizational interactions (customer–supplier relations) are being transformed. Sarkis and Sundararaj (2002) discuss how brokering's role and practice needs to evolve with evolving organizational forms and supporting tools, technologies, and mechanisms needed to implement e-commerce. Also, Turowski (2002) explained how agent-based e-commerce could support the development of a system for customization. More research is required to develop an agent-based modelling to enhance the effectiveness of brokering in SCM.

5.2.3. Virtual enterprise and IT

Virtual enterprise is based on strategic alliances of partners based core competencies. The partners may be dispersed geographically either nationally or internationally. It becomes more complicated to integrate partners with different objectives and platforms to function. This could be achieved by suitable enterprise resource planning systems including e-commerce and IT for a co-operative supported work in such a virtual enterprise environment. Without IT, one could hardly imagine a virtual enterprise development.

There is increasingly growing interest in e-businesses. Its impact on supply chains is currently covered in about 150 articles and article number is growing. Most of them are biased towards the application of e-commerce towards sales and marketing. The supply chain dimension of e-business is largely ignored and managed poorly (van Hoek, 2001). According to van Hoek (2001), the e-supply chain format resulting from these initiative is different from traditional e-commerce and purchasing approaches in that:

- A supply chain-wide information infrastructure is used to directly disseminate relevant market information throughout the chain as a whole, avoiding a loss of time.
- Information is used for long-term innovation and enhanced customer relationship.
- Co-operation among supply chain part.

Clements (1997) presents the issues concerning developing international standards for virtual enterprises. Sarkis and Sundararaj (2002) discussed the evolution of brokering paradigms in e-commerce enabled manufacturing.

5.3. E-commerce and SCM

EC can take a variety of forms such as EDI, direct link-ups with suppliers, Internet, Intranet,

Extranet, electronic catalog ordering, and e-mail. To support the inter-organizational sharing of resources and competencies in network structure, communication and co-ordination need to be maintained. IT has a pivotal role to play in improving communication and co-ordination by acting as an enabler (Love, 1996). E-business is the establishment of a computer network to search and retrieve information in support of business decision making and inter-organizational co-operation (Kalakota and Whinston, 1996).

The Internet helps to manage supply chain activities by offering information about what kind of product is demanded, what is available in the warehouse, what is in the manufacturing process, and what is entering and exiting the physical facilities and customer sites (Lancioni et al., 2000). For example, ERP systems such as SAP, via Extranets connect not only different functions within a firm but also among the firm's supply chain partners (i.e. suppliers, distributors, and third party logistics (3PL) providers), enabling the partners to share information such as order status, product schedules, and sales records, to integrate major supply chain processes and to plan production, logistics and marketing promotions (Overby and Min, 2001). Naylor et al. (1999) discuss the role of IT in integrating the lean and agile manufacturing paradigms in the total supply chain. Webster (1995) highlights the power of EDI in supporting collaboration and resolving conflict in a supply chain.

5.3.1. Purchasing

The increased popularity of e-commerce is due to a multitude of operational benefits it can bring to purchasing practices. Examples of these benefits are cost savings resulting from reduced paper transactions, shorter order cycle time and the subsequent inventory reduction resulting from speedy transmission of purchase order related information, and enhanced opportunities for the supplier/buyer partnership through establishment of a web of business-to-business communication networks. In spite of these benefits, EC purchasing has serious problems to the successful implementation of a cyber-purchasing system include a host of security, legal, and financial problems (Min and Galle, 1999).

McIvor et al. (2000) have explored how electronic commerce can fundamentally change the inter-organizational processes at the buyer-supplier interface. E-commerce is changing the competitive environment in a number of ways: (a) reshaping buyer-supplier relationships, (ii) improving core business processes, (iii) providing electronic intermediation, and (iv) reaching new segments and markets.

Emmelhainz (1990), Carbone (1995) and Gupta (1997) have discussed the operational benefits of business-to-business purchase cyber-purchasing. Min and Galle (1999) identified the potential problems of purchasing online. Some of the major issues in cyber purchasing include size of the firms, security concerns, global sourcing, contract laws and government regulations. EC success depends on the degree of acceptance and the extent of participation among suppliers due to the interdependent nature of EC. Croom (2001) examines the optimization of purchasing for maintenance, repair and operating supplies (MRO) through purchase process reengineering. The use and development of the Internet as a channel for procurement of MRO items was examined from a transaction cost perspective.

According to Wang (2000), e-commerce should be viewed less as a phenomenon of business online and more as a challenge of organization redesign. He has proposed a quasi-general organizational design approach for EC projects. These approaches emphasize the organizational support for the EC strategy identification, network organization design, task design, and reward design in the EC age. However, each business process takes its own organizational structure and IT infrastructures. The Internet has the scope to transfer complex information accurately and to reduce the delays as information passes up and down the supply chain (Elliman and Orange, 2000; Emiliani, 2000).

5.3.2. Operations

Internet trade is not without problems for the supplier. They also discuss several issues of interoperability, building trust, confidence and security; and the need for a regulatory and legal framework. Murillo (2001) discusses the implications

of e-commerce on supply chain management and its effectiveness. Emiliani and Stec (2001) discuss the terms and conditions for the online auction and purchasing contracts. Build-to-order (BTO) not only requires Just-In-Time (JIT), but also the most advanced computerized versions of ERP. With its facilitation of real-time communications between suppliers, production functions, marketing functions and the final customer, e-commerce has become an inherent component of BTO (Doherty, 2000).

Kehoe and Boughton (2001) discuss some of the key elements of research that will investigate the role of the Internet within the manufacturing supply chain and these are (a) a detailed examination of the current usage and operation of the Internet within manufacturing supply chains, and establishing industry practice in this area, (b) building a dynamic model of the web-based supply chain in each of the collaborative industrial sectors, (c) HTML prototype for the supply web model, and (d) sector-based models and prototypes.

Nowadays, collaborative network of partners is more popular with companies than before to be flexible and responsive to changing market/customer requirements. These collaborative network of partners are emerging to support business to consumers (B2C), B2B and government to citizen interactivity through Intranets (Hackney et al., 2000; Marshall and McKay, 2000). Lot of attention is focused towards B2B e-commerce. There are numerous web-based exchanges that connect buyers and suppliers in real-time having a significant impact on procurement and supply chain management. Most of the B2B activity falls under the sphere of portals that dynamically match buyers and sellers or e-procurement, where buyers and sellers are aggregated (Kaplan and Sawhney, 2000).

The adoption of more integrated Internet-commerce (I-commerce) models should strengthen the relationship between a network orientation and global supply chain management. Not only the Internet make foreign markets more accessible, it now makes it much easier to integrate foreign customers, suppliers, and intermediaries into closely managed supply chain relationships, boosting savings and speeding innovation (Overby and Min, 2001). The emergence of e-commerce will only accentuates this move towards collaboration as technology creates the ability to forge relationships more effectively and efficiently (Fontanella, 2000). For instance, Dell now maintains over 3000 tailored domains for customers. Such differentiation services, not possible prior to the proliferation of the Internet, allow companies to compete on factors other than price and to forge valuable relationships. Companies like Dell assert that such efforts will actually conserve organizational resources and result in positive returns (Frook, 1998). Supply chains are especially well suited for the fast changing I-commerce environment, as organizations are able to enter and evolve much more quickly and efficiently than organizations in traditional joint ventures or vertical integration arrangements. Ball and Wright (2000) examine the information value chain and some of its concepts, first for printed information and second for electronic information.

5.3.3. Logistics

Emiliani (2000) describes the process for conducting downward price B2B online auctions over the Internet for direct material purchasing and presents common issues, process improvement opportunities, and the interpretation of auction results. Van Hoek and Chong (2001) present the experiences of UPS Worldwide Logistics, a company known to be leading in the development and implementation of a fourth-party business model. This model applies information integration initially in logistics and transport operations. But UPS WWL has achieved full supply chain integration and strategic applications of the information availability to the benefits of the clients. It also includes supply web practices in which multiple players' team up flexibly to align to the end consumer.

Clarke (1998) presents the concept of ''virtual logistics''. With virtual logistics, the physical and information aspects of logistics operations are treated independently from each other. In such operations, ownership and control of resources is effected through the Internet (or the Intranet) applications rather than direct physical control, and

resources can, thereby, be owned and utilized remotely.

Damen (2001) developed service-controlled agile logistics as a new model for a logistics control system that fulfills (a) information driven logistics system, (b) user-friendly logistics services, and (c) use of modern IT tools for logistic services. Many researchers explained the close links between information systems and the management of logistics (Christopher, 1997; Cooper, 1994; Feraud, 1998). Chiu (1995) presented an integrated framework for distribution firms to establish and so improve their distribution systems. Also, highlighted the role of IT in improving the efficiency of logistics value chain. E-logistics has been gaining ground after companies selected to go for third party logistics. The experiences reported indicate the IT is an indispensable tool for logistic operations.

5.4. Infrastructure for IT in SCM

Infrastructure for IT in SCM consists of Internet connectivity, hardware and software including application systems integration. Nevertheless, training and education cell for IT is important to fully utilize the IT available for SCM. There are different IT platforms and systems available to enable the application of IT in SCM (Haeckel, 1999).

Walsh and Koumpis (1998) presented a decomposable, "autonomous agents" approach was adopted to specify information supply chain "agents" (e.g. suppliers, buyers, distributors, etc.), including their structural relationships, interaction "protocols" and co-ordination policies. Jayaram et al. (2000) present an empirical study of 57 top-tier supplier to the North American automotive industry examined the direct and complementary effects of information system infrastructure (ISI) and process improvements on time-based performance.

In evaluating the formation of customer–supplier relationships, Sarkis and Sundararaj (2002) focus on two major dimensions that will influence the formation process. The first is the type of organizational structure and relationships, and the second major dimension is the electronic commerce environment.

5.4.1. Organizational

Adaptation of e-business infrastructure involves deep level changes that affect core elements of an organization, including mission, vision, business strategy, goals, culture, technology, training and policies (Mukherji and Mukherji, 1998). The organizational infrastructure requirements include top management involvement, strategic fitness of IT, major players in the organization (power brokers), IT skills available, etc. An organization should be a learning unit so that the IT can be absorbed for the benefit of SCM.

Attaran (2001) focuses on the organizational characteristics of online procurement systems which requires in-house expertise, employees' education, content management, content rationalization, business process reengineering (BPR) implementation, do not count on downsizing and better communication. These seven caveats of effective web-based procurement. Cheng et al. (2001) present an e-business infrastructure for construction. The infrastructure focuses on resource planning, teamwork, process improvement tools and techniques, and information management, training and development, and performance measurement. The information systems for supply chain management should be accessibility, compatibility, user-friendly, stability and reliability, minimal training and strong after-sales service.

Klouwenberg et al. (1995) argue that the distinction between business architecture and IT architecture is of major importance. In many organizations, the architecture is mainly determined by technical and economical considerations. The organizational aspects are therefore mainly realized by means of the technical opportunities (technology push) and not on the basis of strategic and/or organizational considerations. Within the scope of the business needs, the business architecture offers the possibility to choose the best IT solutions.

5.4.2. Technological

The industrial revolution that took place in the past decade can be traced to technological innovation such as the Internet and the web. Subsequently, ERP systems have played a major in developing SCM. Also, developments in hardware

and telecommunication technologies have occurred in order to meet the rising demands from companies. The ERP systems represent an optimum technology infrastructure that when integrated properly with a process-oriented business design can support the supply chain management systems effectively (Hicks, 1997; Mullin, 1997).

Lau and Lee (2000) propose an infrastructure of a supply chain information system, focusing on the component module necessary for the building up of such a system with a description of the creation of these modules. The proposed supply chain embraces the concept of distributed object technology to enable efficient data exchange among various data objects that may reside in distributed platforms over geographically isolated regions. Huang and Mak (2000) develop an overall methodology for enabling better supplier involvement in new product development process and to demonstrate the framework through a prototype of web-based platform on the Internet/intranets using the web technology.

Au and Ho (2002) discuss the B2B e-commerce enabled supply chain management and present the IT infrastructure required for SCM. Jayaram et al. (2000) study the effects of information system infrastructure and process improvements on supply chain time performance. They found that the IT factor along with process improvement variables (standardization and concurrent engineering, CE) had a complementary and significant positive influence on supply chain time performance.

SAP R/3 has been widely implemented to create value-oriented supply chains that enable a high level of integration, improve communication within internal and external business networks, and enhance the decision-making process. Al-Mashari and Zairi (2000) discussed the SAP/R3 implementation case for reengineering supply chain and highlight the importance of IT infrastructure for the successful implementation of SAP/R3 for the reengineering supply chain. Perry and Sohal (2000) analyzed quick response practices and technologies such as EDI, computer-aided design and computer-aided manufacturing in developing supply chains. Sharma and Gupta (2002) present the application of web-centric to improve agility and reduce costs. They provide an overview of various application service providers (ASP) and issues and challenges. They also discuss the IT infrastructure required for application service providers. Yamaya et al. (2002) discuss about delivering ERP systems through ASP.

5.5. Knowledge and IT management in SCM

Knowledge management is concerned with recognizing and managing all of an organization's intellectual assets to meet its business objectives. Organizations are redesigning their internal structure and their external relationships, creating knowledge networks to facilitate improved communication of data, information, and knowledge, while improving co-ordination, decision making, and planning (Warkentin et al., 2001). Knowledge networks allow their participants to create, share, and use strategic knowledge to improve operational and strategic efficiency and effectiveness. E-business knowledge can be created and shared more effectively by a combination of new organizational designs and adoption of new technologies, such as data mining and intelligent agents. Managers are beginning to leverage their information system assets to react to market demands more efficiently. For example, in a B2B environment, different kinds of relationships or partnerships at different times. Partnership is critical to the creation and spread of knowledge, and creation and diffusion of innovations (Jutla et al., 2002).

5.5.1. Technology management

Information technologies such as XML for representing corporate data, ERP infrastructure that provides support for logistics operations, and web infrastructure allow B2B e-commerce successful or SCM. In the emerging e-procurement marketplaces, firms establish efficient web-based electronic relationships that allow for closer integration between buyer–supplier. The reliance on application service providers for high-value e-procurement and other business purchases makes the reliability of knowledge transfer paramount. Clearly, exchanging information must be consistent between buyer to portal and portal to seller and between seller to portal and portal to buyer (Warkentin et al., 2001).

Talluri (2000) in his paper highlights the importance of the efficient use of information technologies/information systems at strategic, tactical and operational levels of SCM. He presented a multi-objective mathematical model for effective acquisition and justification of IT/IS systems for SCM. Spekman et al. (2002) argue that effective management of one's supply chain is not easily accomplished. They develop this capability as a core skill that will ultimately separate the winners from the losers. They develop the concept of supply chain competence and use learning as a proxy.

Boubekri (2001) describes how ERP is increasingly being used as a technology enabler for SCM and problems associated with its implementation. Motwani et al. (2000) explain the role of IT in managing global technology. There are several researchers (Angeles and Nath, 2000; Nah et al., 2001) whom deal with the information technology management in a supply chain perspectives.

5.5.2. Education and training

Education and training are the most important component of any change process in an organization. In order to be successful, it is important that we have the full co-operation of employees at all levels; otherwise, technologies alone will not help to improve the organizational competitiveness. To implement and subsequently use any IT/IS, workforce needs to be motivated to work in a transparent and open communication environment. Knowledge workers are important to be successful in capital or technology intensive operations environments. Tracey and Smith-Doerflein (2001) point out that the human dimension of communication and co-operation across all parties comprises the chain. Van Hoek makes a case for a stronger focus on integrating hot topics and research skill development in logistics courses.

5.6. Implementation of IT in SCM

People and processes in an organization must undergo significant change, learning, adaptation and growth in response to the introduction of IT. The changes are often drastic and cause intra-organizational tensions (Kuruppuarachchi et al., 2002). Integration of the supply chain's activities and processes before development and implementation of the information systems in SCM is needed. Cumberland Packaging Corporation decided to replace its 20-year-old manufacturing system with a fully integrated ERP solution. After a careful evaluation, the company decided to deploy ADAGE, the powerful ERP and SCM solution from SCT Corporation. ADAGE is an object-oriented, fully graphical software solution designed specifically for the process and hybrid industries. By implementing ADAGE Cumberland has been able to reduce inventory by 10–15%, or approximately $2 million worth. In addition, the system has helped Cumberland shorten delivery lead-times, improve customer service, and better plan and forecast demand, thereby cutting production costs (http://www.sctcorp.com/SMDS/ClientProfiles.htm).

5.6.1. Organizational

Successful implementation of IT as an enabler of SCM depends upon the support of top management and overall organizational structure. The nature of skills available within an organization influences the success of IT in supply chain. Management of quality, risk and people are specific considerations in every IT project and these should be carried out over the life cycle of a project.

McIvor et al. (2000) show how electronic commerce can fundamentally change the inter-organizational processes at the interface between the buyer and supplier. It is shown how electronic commerce is not only enabling the redesign of internal organizational processes, but is extended into both the buyer and supplier organizations. They have presented three case studies outlining how various electronic commerce technologies have been implemented in a number of buyer-supplier environments. Ho (1996) discussed in detail IT implementation strategies for manufacturing organizations. Decisions of a structural nature contain three dimensions: system competencies, (ii) technology scope, and (iii) IT alliance.

5.6.2. Methodological

Methodological issues of IT implementation in SCM indicate the approach employed. For exam-

ple, some companies choose to reengineer their business process with the objective of implementing IT and hence improve their performance. Also, project management and planning method can be sued for the implementation of IT in SCM. There are different tools that could be used for the implementation of IT in SCM and some of them include (i) quality function deployment (QFD), (ii) concurrent engineering, and (iii) life cycle approach (Scott, 1996).

Lauer (2000) describes the role played by a very active industry interest group that has served as a supporter and advocate for the adoption of EDI within the automotive supply chain. Some suppliers were unable to absorb the increasingly technological and unforgiving business environment, may either go bankrupt or sell out to their more powerful and agile competitors. Al-Mashari and Zairi (2000) presented a framework for effective SAP R/3 implementation that includes: (1) business case, (2) benchmarking, (3) implementation strategy, (4) project management infrastructure, (5) change management, (6) BPR, (7) SAP R/3 installation. Angeles and Nath (2000) examine the importance of congruence between trading partners, along several dimensions, for the successful implementation of EDI networks. Williams et al. (1998) found that firms that were more methodical in choosing their trading partners were more likely to achieve greater range, depth, and width of EDI usage.

Pawar and Driva (2000) highlight six major issues in the implementation of EDI in supply chain environment to improve the success of the implementation framework that include the following steps: (i) develop strategy, (ii) assessment, (iii) create culture, (iv) prioritize improvements, (v) plan the change, (vi) implement improved situation and support implementation. Calza and Passaro (1997) present the experiences of reorganization of Unilever-Sagit's logistics system. The reorganization of the logistics structure meets two requirements: (i) higher efficiency through the optimization of the product and information flows, (ii) higher effectiveness through progressive rebalancing of the prevailing role played by the supply chain. Cooper and Zmud (1990) propose a technological diffusion approach for information technology implementation. In the networked and collaborative enterprise environment, this diffusion approach will be appropriate.

5.6.3. Human resource

Human factors such as the behavioral attitude towards the implementation of IT in SCM, level of education, knowledge in computers, international exposure, training and education, reward and employee empowerment and incentive scheme impact the successful implementation of IT in SCM. Calza and Passaro (1997) examine the effects generated by the implementation of EDI technology on supply chain management. They discuss the theoretical aspects of the impact of EDI on strategic management of logistics and examine the Unilver-Sagit EDI network in the detail.

Williford and Chang (1999) describe the development of a macro model that predicts staffing, training and infrastructure funding over a five-year period for the FedEx Information Technology Division. A system dynamics model was built using regressions on business; system and productivity metrics coupled with business projections.

6. A framework for identification and application of IT in SCM

In this section, a framework has been presented for identifying the implications and applications of IT in SCM. This framework is based on the review of literature on IT in SCM. Critically reviewing the literature helped to identify the major strategies, enabling technologies and critical success factors for the application of IT in SCM. This framework is based on the following the logical development of discussions on the applications of IT in SCM:

(i) The literature available (selected) on IT in SCM has been classified based on the nature of IT and applications, major areas of decision making and major enabling strategies and technologies with the objective of achieving the full potential of IT in developing and managing an effective supply chain.
(ii) The sub-classification of the literature is aimed to assist both the researchers and

practitioners in identifying the potential areas of development and critical success factors for the successful application of IT in SCM.

(iii) Subsequently, the gap between theory and practice and major tools used for modelling and analysis of IT in supply chain environments are discussed in this section.

The major issues that need to be addressed when attempting to enhance the role of IT in supply chain integration are discussed in this section along the criteria that have been used for literature classification and review that include: (a) strategic planning for IT in SCM, (b) virtual enterprise and SCM, (c) e-commerce and SCM, (d) infrastructure for IT in SCM, (e) knowledge and IT management in SCM, and (f) implementation of IT in SCM. The details follow hereunder.

6.1. Strategic planning

Strategic planning of IT in SCM has the objective of making long-term decisions such as the selection and productive implementation of IT with the objective of achieving an effective and well-connected supply chain. Considering the characteristics of SCM, long-term decisions should promote functional co-operation as well as extended enterprise integration. IT plays a major role in both integration and creating demand/market for products/services in SCM.

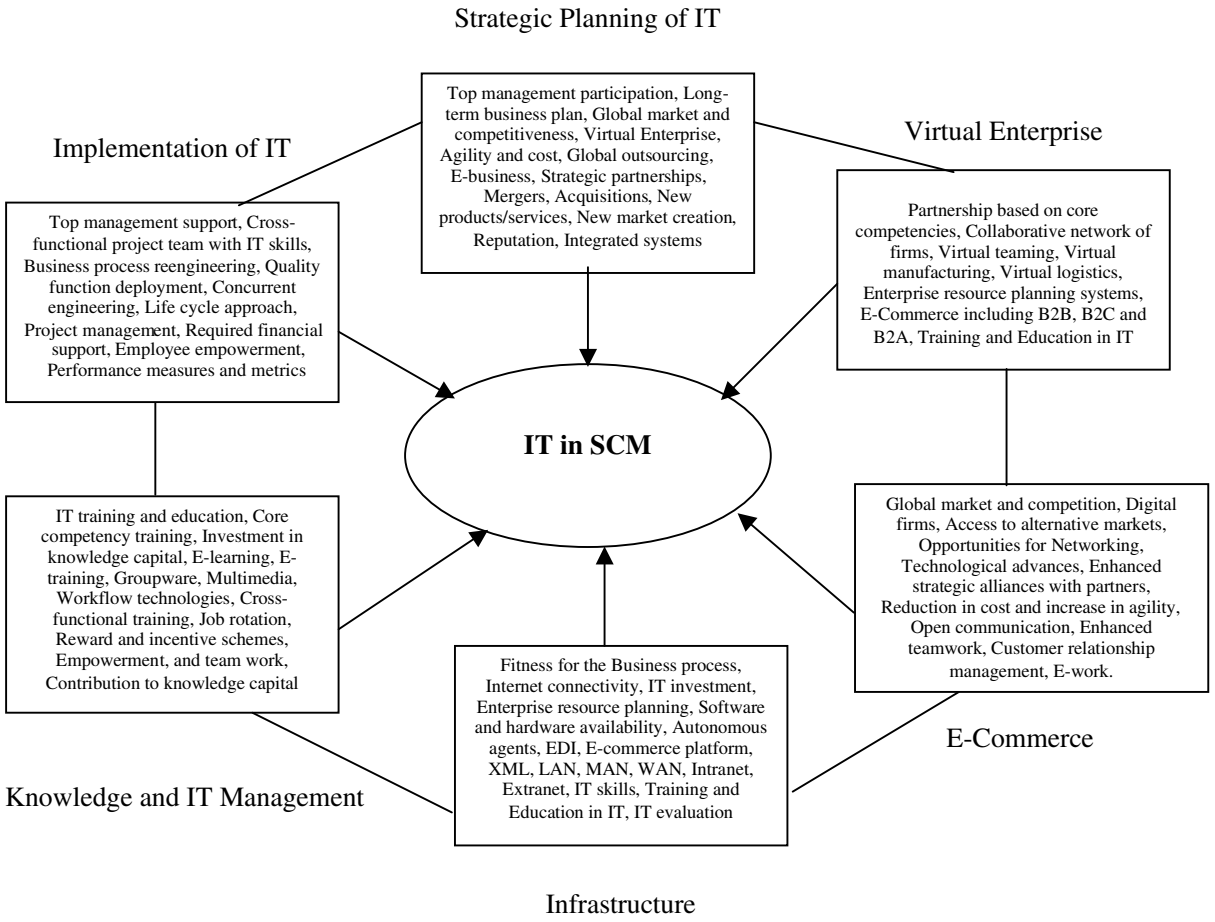

Fig. 1. A framework for the development of IT for effective SCM.

As depicted in Fig. 1, top management participation is important in making strategic decisions in particular, IT investment decisions to achieve an effective SCM system. It is not just the implementation of a piece of software, but it requires some major changes in business processes and a way the company operates. This requires considerable investment in both capital and people. Since the market has become global due to trade liberalization policies and e-commerce, it is essential a company chooses the option of global outsourcing or virtual enterprise that is based on core competencies with the objective of being agile to meet the changing market requirements. This requires strategic decisions such as merger and acquisitions with a view to reach the market as quickly as possible and that too with the right products/services.

The literature on the strategic planning of IT-enabled SCM is further classified into marketing, economical, organizational and technological perspectives of IT in SCM. The following are the examples of strategic planning for different areas of IT in SCM:

- Some companies can implement an IT system to develop an effective SCM if it has to compete in a market where the speed of delivery and quality are important.
- In order to receive financial and technical support from the government (in particular SMEs), companies implement an IT system to improve their supply chain performance.
- Companies have to compete along multiple competitive performance objectives, this requires the cost reduction as a key criterion, therefore, and they can go for, for example, an Internet-enabled supply chain management.
- Companies have to restructure their business processes with the objective of achieving lean production by implementing an IT system to eliminate non-value-adding activities by improving the communication along the value chain.
- Companies need to develop their e-commerce web site for creating a good image with their customers on technology competencies.

Similar to these, there are so many strategic reasons, companies choose to go for IT-enabled SCM. To summarize, the flexibility and responsiveness, globalization, new and innovative products, new markets (fleeting opportunities) and mergers and acquisitions are the major reasons for IT in SCM are the major reasons for IT in SCM.

Many companies fail to consider the long-term implications of not investing in IT for achieving an effective supply chain. Also, assuming that the company is doing well currently and they do not need any IT means the lack of strategic thinking. May be within the next few years, the company will loose its competitive position. Therefore, constant revision of strategies is important to take into account the changes in the market environment and technological development. This is applicable for strategic planning of IT for SCM. Researchers should focus on developing computer-aided models for analyzing the strategic implications of IT in SCM taking into account both the internal and external factors to an organization. Since the top management does not have much time to go through a large volume of information, a system that encourages executive information perspective would be helpful. For this, fuzzy logic and object-oriented modelling can be helpful including simulation. Game theory models and simulation would be to make strategic decisions regarding the selection and implementation of IT for SCM. Practitioners should focus on developing a consortium and strategic alliances to develop an appropriate strategy for IT.

6.2. Virtual enterprise and SCM

Developing a VE/VO is one of the most important strategic applications of IT in today's business environment. VE/VO becomes an important strategy for achieving agility in supply chain. Without IT, it is difficult for a company to develop a virtual enterprise. This type of enterprise is made up of collaborating partners who are offering different products/services based on their core competencies. Partnership selection is based on a set of predetermined criteria taking into account the nature of business model. Some of them include their past performance along competitive performance objectives, strategic objectives, infrastructure and IT systems and skills, etc. Virtual

enterprise includes virtual reality in as many areas as possible. For example, virtual manufacturing helps to effectively manage operations. Computer-based design enables to reduce the product development cycle time.

Virtual logistics using e-commerce (web-enabled logistics information system) will contribute to the agility of an organization. Considering the importance of IT system in integrating the activities of collaborating partners various IT systems have been implemented. Some of them include ERP systems (SAP, BAAN, Peoplesoft, JD Edwards, and ORACLE). Different e-commerce applications like B2B, business to consumers and business to administration would support the operations of virtual enterprise. Virtual enterprise requires people trained in communicating with different languages and culture together with an understanding about the strategic objectives. Sufficient training in information technology including JAVA, XML and web development is required for the development of a VE/VO. Suitable architecture for VE/VO and standards for IT system need to be developed for effectively developing and managing an IT-enabled supply chain. These issues offer greater challenges to practitioners to develop a framework for VE and IT system. Again, companies in a particular industry can come together to develop a joint team for this purpose. Investing in such research projects is a worthwhile effort.

Companies are unable to conceptualize the idea of virtual enterprise. Many believe this is a hypothetical system that can not be put into practice. However, many companies have been successful with the virtual enterprise based on strategic alliances and partnership development. The main objective here should be to convince the practitioners about the benefits of virtual enterprise. This requires education and training, perhaps researchers can contribute to this effort. Also, the concept of VE can be used and not necessarily duplicate other systems, which means focusing on core business processes and attempt to outsource them using strategic alliances. Before doing this, companies have to evaluate themselves about to what extent their IT systems support the integration of partners along the supply chain. Otherwise, one could hardly achieve the benefits of VE. Companies need to assess their business process and IT environment and the VE, so that a suitable framework can be developed based on the overall support available from the company. Researchers can develop conceptual frameworks to understand the role of IT and structure of VE, and hence to develop both analytical and simulation models for selecting suppliers/partners and IT based on their business strategic goals. For this, agent-based simulation modelling, multi-criteria decision-making and linear programming methods could be used. Many information-sharing systems and collaborative-supported systems including collaborative teams should be employed for integration of activities in VE.

6.3. E-commerce and SCM

The impact of e-commerce on SCM is much larger as it facilitates inter-organizational communication and in turn reduces cycle times and develops collaborative work. E-commerce provides opportunities for an organization to expand their markets worldwide. Once a company places its products/services, it can expect an increase in demand. This requires a SCM system, which effectively meet the growing demand. Also, the supply chain should be agile in meeting customized online requirements. This could well be achieved by VE and ERP systems. E-commerce opens up the communication and enlarges the networking opportunities. E-commerce supports seamless integration of partnering firms. This facilitates an increase in agility and a reduction in cost. Enhanced teamwork and customer relationship management (CRM) for designing new products and receiving feedback from customers and being proactive on responding to changing market requirements.

Considering the recent trend in e-commerce, more and more companies are attempting to sell their products/services on e-commerce. There variety of e-commerce models available depending upon the transactions that take place between different parties. For example, B2C, B2B and customer to customer are some examples of e-commerce models. For effective SCM, B2B

e-commerce models would be appropriate. To improve the communication between customers and suppliers, Internet, web and EDI would be useful in exchanging the information about products and services. Many companies lack knowledge and skills about e-commerce. This could be due to lack of understanding of the implications of e-commerce and lack of fund for investment in e-commerce. These require education and training and also government support to facilitate easy access to the Internet service and development of web site for e-commerce. There are still lot of issues related to the Internet speed, logistics (including reverse), customer relationship management, security and ethics should be addressed when B2B is implemented.

6.4. Infrastructure for IT in SCM

Since the demand for high speed Internet services for processing voluminous data, there is a need for high speed Internet Portals. There are many Internet Portals (Yahoo, AOL, JUNO, etc.) offer services to companies to have their products on e-marketplace. However, the system is slow during peak hours. Although companies develop their e-commerce web site with the animation and 3D view of their products/services to improve the quality of interactive marketing with customers. However, this makes the system slow and customers have to wait long to open or view the page. They may loose their patience in buying products online. Hence, there is a need to trade-off between the quantity and quality of information that should be made available on their web site and the speed of access. Developing IT infrastructure requires investment in Internet services, web development and updating. There are many strategies to overcome this; for instance, strategic alliances with partnering IT firms and other partners would help to overcome the technology problems.

Companies should decide the type of networks (Intranet and Extranet) that would be suitable for their business. Also, they need to invest in developing the IT skills of their employees. IT migration is required from time to time based on the changes to the business process and organizational objectives and strategies. This highlights the importance of being learning organization that obviously supports agility in Internet-enabled SCM.

Given the rapid accessibility to customers and suppliers around the world, businesses appear to be turning towards networks of co-operation rather than external control structures (Overby and Min, 2001). Global supply chain with uncertainty driven new network orientation. A network orientation will encourage more integrated levels of the Internet Commerce adoption that in turn further strengthens the relationship between a network orientation and its implementation. A dense networking infrastructure to support digital communications is the obvious backbone of any information society. New broadband and wireless technologies are being funded and developed so that eventually all citizens and businesses will be connected.

The infrastructure question has been crucial for the successful application of IT in SCM. Many companies fail to recognize their weaknesses and strengths in terms of their streamlining their business processes, and lack of knowledge and computer skills. A guidebook could be developed by researchers to assist practitioners in developing infrastructure for achieving an IT-enabled SCM. The optimal investment areas need to be identified in a company taking into account the business goals and financial strength. An intelligent simulation model using object-oriented modelling would be useful for this purpose. Government and industry consortium support are essential for developing (1) B2B e-commerce, (2) e-commerce policies and ethics, and (3) costing system.

6.5. Knowledge and Information Technology management

KM has become one of the strategic uses of IT in today's business environments. Many companies are considering building KM system for organizational learning. However, in networked economy, many companies lack a suitable framework for effectively managing the knowledge and IT considering their life cycles. This requires a systemic evaluation of various knowledge and IT management strategies and techniques. There are different ways to manage the knowledge and IT.

These include strategic alignment with partnering firms, collaboration with local universities and training and education in IT. Knowledge about market and customer expectations can be acquired with web-based information systems. This opens up the whole world of information. However, it is unlikely that companies can let their employees to spend unlimited amount of time in searching through voluminous information. Therefore, data mining and data warehousing techniques will help to improve the speed of data processing and hence make available the right information for making timely and more accurate decisions.

Researchers are yet to come up with precise strategies and methods for managing knowledge and IT in supply chain environment. The management of knowledge and IT requires planning, co-ordinating and controlling of activities. This requires constant updating of the knowledge and IT available in an organization. No company has unlimited resources, therefore, suitable and critical areas need to be identified with the objective of optimizing the investment in knowledge and IT projects and at the same time achieving maximum benefits. Various decision models need to be developed for decision making in the areas of knowledge and information technology management. Tools such as project management can be used to optimize the completion time with the limited resources available. Common industry fund needs to be established for training and education on new technologies and strategies of IT in SCM.

6.6. Implementation issues of IT in SCM

Implementation of IT to achieve agility in a supply chain requires a strong team that can include key and IT knowledgeable managers from all functional areas. A well-documented implementation plan is required for IT in developing an effective supply chain. Moreover, the top management support and involvement are essential for the successful implementation of IT in SCM. Implementation may require making necessary changes to organizational business processes with the objective of absorbing the IT system such as SAP and CAD/CAM. Before implementing IT, there is a need to look at the business model and then identify suitable IT systems required to support the objective of achieving agility in a supply chain.

There are several tools and methods available for effectively managing the implementation of IT for responsive supply chain and some them can include QFD, CE and life cycle approach. Top management should encourage the empowered implementation team to cut across the functional barriers and provide with necessary technical and financial support to achieve a productive supply chain with suitable IT systems. Suitable performance measures and metrics should be developed to monitor the implementation of IT over a time period. This will also include planning phase, pilot phase and go live.

Besides, business process reengineering has been considered as one of the most important strategies for streamlining the business process. IT is an important component of reengineering business process by eliminating non-value-added activities in a supply chain. BPR and IT compliment each other in their efforts to achieve dramatic improvements by radical changes. IT plays an important role in BPR as the speed, information processing capabilities and connectivity of computers can increase the efficiency of business processes and communications in the SCM systems.

Implementation of IT for achieving an effective supply chain warrants suitable framework that is based on theoretical analysis and past experiences. More case studies and benchmarking studies would be useful. Strategic alliances and benchmarking studies on implementing IT for SCM would be helpful. Lack of case studies and empirical research continue to put the companies behind in terms of coming forward to implement various IT for achieving an integrated SCM.

7. Concluding remarks

It has been demonstrated that IT is an essential ingredient for business survival and improves the competitiveness of firms. As a result of the literature review, we can see that IT has a tremendous influence on achieving an effective SCM. Integrating the supply chain activities is driven by the

need to streamline operations to achieve quality service to customers. There are many research articles on IT in SCM, but there is a lack of critical review of the literature with the objective of bring out the pertinent factors that would influence the successful application of IT in SCM. In this paper, an attempt has been made to review the literature on IT in SCM and to develop a framework for the development and implementation of IT in SCM.

The literature available on IT in SCM has been reviewed based on the major components of IT-enabled SCM. Although the literature survey is not exhaustive, it serves as a comprehensive base for an understanding of IT in SCM. This classification has the objective of bringing out pertinent factors that would support practitioners in their efforts to successfully achieving an IT-enabled SCM. As a result of the literature survey, the major components of IT-enabled SCM comprises of six major areas: (i) strategic planning, (ii) virtual enterprise, (iii) e-commerce, (iv) infrastructure, (v) knowledge and IT management and (vi) implementation. The foundations of a well-developed IT-enabled SCM lie in the preparation of the ground factors of strategic planning and infrastructure from which all development emanates. IT in supply chain strategy needs to be determined by the senior executives in strategic plan. Senior managers and planners should understand that the importance of IT in supply chain and realize that without support of IT systems, it is difficult to provides information for making the best supply chain decisions.

Besides, the following are comments that derived from the literature survey on IT in SCM:

- The strategic information systems should include the strategic objectives of SCM.
- Information systems architecture needs to be designed for SCM that could be different from that of traditional organizations.
- Successful strategic information systems are not easy to implement in SCM. They require major changes in how a business operates internally and with external partner.
- Commercial enterprise information systems require flexibility in order to accommodate individual organizational characteristics.
- Performance measures and metrics need to be established for measuring the performance and suitability of IT in SCM.
- There is a need for developing standards and legal frameworks for the application of IT in SCM.
- The alignment between information model and supply chain model or objectives needs further investigation.

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References

Al-Mashari, M., Zairi, M., 2000. Supply chain re-engineering using enterprise resource planning (ERP) systems: An analysis of a SAP R/3 implementation case. International Journal of Physical Distribution & Logistics Management 30 (3/4), 296–313.

Alshawi, A., 2001. Logistics in the Internet age: Towards a holistic information and processes picture. Logistics Information Management 14 (4), 235–241.

Andersen, T.J., 2001. Information technology, strategic decision making approaches and organizational performance in different industrial settings. Journal of Strategic Information Systems 10, 101–119.

Ang, C.-L., Davies, M., Finlay, P.N., 2000. Measures to assess the impact of information technology on quality management. International Journal of Quality & Reliability Management 17 (1), 42–65.

Angeles, R., Nath, R., 2000. The importance of congruence in implementing electronic data interchange systems. Supply Chain Management: An International Journal 5 (4), 198–205.

Armstrong, A., Hagel III, J., 1996. The real value of online communities. Harvard Business Review (May/June), 134–140.

Attaran, M., 2001. The coming age of online procurement. Industrial Management & Data Systems 101 (1), 177–180.

Au, K.F., Ho, D.C.K., 2002. Electronic commerce and supply chain management: Value-adding service for clothing manufacturing. Integrated Manufacturing Systems 13 (4), 247–255.

Bal, J., Gundry, J., 1999. Virtual teaming in the automotive supply chain. Team Performance Management: An International Journal 5 (6), 174–193.

Ball, D., Wright, S., 2000. Procuring electronic information: New business models in the context of the supply chain. Library Consortium Management: An International Journal 2 (7), 145–158.

Benjamin, R., Wigand, R., 1995. Electronic markets and virtual value chains on the information superhighway. Sloan Management Review 36 (2), 66–72.

Bhatt, G.D., Emdad, A.F., 2001. An analysis of the virtual value chain in electronic commerce. Logistics Information Management 1/2, 78–84.

Black, J.A., Edwards, S., 2000. Emergence of virtual or network organizations: Fad or feature. Journal of Organizational Change 13 (6), 567–576.

Boardman, J.T., Clegg, B.T., 2001. Structured engagement in the extended enterprise. International Journal of Operations & Production Management 21 (5/6), 795–811.

Boubekri, N., 2001. Technology enablers for supply chain management. Integrated Manufacturing Systems 12 (6), 394–399.

Bowersox, D.J., Daugherty, P.J., 1995. Logistics paradigms: The impact of information technology. Journal of Business Logistics 16 (1), 65–80.

Bradley, P., 1999. Managers look to supply chain to cut costs. Logistics Management and Distribution Report 38 (1), 21–22.

Brown, S.L., Eisenhardt, K.M., 1998. Competing on the Edge: Strategy as Structured Chaos. Harvard Business School Press, Boston, MA.

Browne, J., Zhang, J., 1999. Extended and virtual enterprises—similarities and difference. International Journal of Agile Management Systems 1 (1), 30–36.

Calza, F., Passaro, R., 1997. EDI network and logistics management at Unilver-Sagit. Supply Chain Management 2 (4), 158–170.

Carbone, J., 1995. Buyers find sources on Internet. Purchasing (December 14), 81–82.

Cerpa, N., Verner, N.M., 1998. Case study: The effect of IS maturity on information systems strategic planning. Information & Management 34, 199–208.

Cheng, E.W.L., Li, H., Love, P.E.D., Irani, Z., 2001. An e-business model to support supply chain activities in construction. Logistics Information Management 14 (1/2), 68–77.

Chiu, H.N., 1995. The integrated logistics management system: A framework and case study. International Journal of Physical Distribution & Logistics Management 25 (6), 4–22.

Christiaanse, E., Kumar, K., 2000. ICT-enabled coordination of dynamic supply webs. International Journal of Physical Distribution & Logistics Management 30 (3/4), 268–285.

Christopher, M., 1997. Marketing Logistics. Butterworth-Heineman, Oxford.

Clarke, M.P., 1998. Virtual logistics: An introduction and overview of the concepts. International Journal of Physical Distribution & Logistics Management 28 (7), 486–507.

Clements, P., 1997. Standards support for the virtual enterprise. Assembly Automation 17 (4), 307–314.

Cooper, J., 1994. Logistics & Distribution Planning: Strategies for Management, second ed. Kogan Page, London.

Cooper, R.B., Zmud, R.W., 1990. Information technology implementation research: A technological diffusion approach. Management Science 36 (2), 123–139.

Croom, S., 2001. Restructuring supply chains through information channel innovation. International Journal of Operations & Production Management 21 (4), 504–515.

Damen, J.T.W., 2001. Service-controlled agile logistics. Logistics Information Management 14 (3), 185–195.

Daniels, S., 1998. The strategic use of information systems. Work Study 47 (5), 167–171.

Davidow, W., Malone, M., 1992. The Virtual Corporation—Structuring and Revitalizing the Corporation for the 21st Century. Harper-Collins Publishers.

Doherty, J., 2000. Learning the B-to-B-Bs. Barron's (March, 13).

Dos Santos, B.L., 1991. Justifying investments in new information technologies. Journal of Management Information Systems 7 (4), 71–90.

Elliman, T., Orange, G., 2000. Electronic commerce to support construction design and supply chain management: A research note. International Journal of Physical Distribution & Logistics 30 (3/4), 345–360.

Emiliani, M.L., Stec, D.J., 2001. Online reverse auction purchasing contracts. Supply Chain Management: An International Journal 6 (3), 101–105.

Emiliani, M.L., 2000. Business-to-business online auctions: Key issues for purchasing process improvement. Supply Chain Management: An International Journal 5 (4), 176–186.

Emmelhainz, M.A., 1990. EDI: A Total Management Guide. Van Nostrand Reinhold, New York, NY.

Feraud, G.J.S., 1998. Improving strategic decision making in logistics information management—a framework. Logistics Information Management 11 (4), 232–243.

Fletcher, K., Wright, G., 1996. The strategic context for information systems use: An empirical study of the financial services industry. International Journal of Information Management 16 (2), 119–131.

Fontanella, J., 2000. The web-based supply chain. Supply Chain Management Review 3 (4), 17–20.

Frook, J.E., 1998. Future trend: Getting personal with customers. Internet Week 720 (22 June), 11.

Gallupe, R.B., Dennis, A.R., Cooper, W.H., Nunamaker, J.F., 1992. Electronic brainstorming and group size. Academy of Management Journal 35, 350–369.

Graham, G., Hardaker, G., 2000. Supply-chain management across the Internet. International Journal of Physical Distribution & Logistics Management 30 (3/4), 286–295.

Gupta, U.G., 1997. The new revolution: Intranets not Internet. Production and Inventory Management Journal 38 (2), 16–20.

Hackney, R., Burn, J., Dhillon, G., 2000. SPECS: A new approach to strategic planning for e-commerce systems. In: Proceedings of the Americas Conference on Information Systems, pp. 843–847.

Haeckel, S.H., 1999. Adaptive Enterprise: Creating and Leading Sense-and-Respond Organizations. Harvard Business School Press, Boston, MA.

Henderson, J.C., Venkataraman, N., 1993. Strategic alignment: Leveraging information technology for transforming organizations. IBM Systems Journal 32 (1), 4–16.

Hicks, D., 1997. The managers' guide to supply chain and logistics problem-solving tools and techniques. IIE Solutions 29 (10), 24–29.

Ho, C.F., 1996. Information technology implementation strategies for manufacturing organizations. International Journal of Operations & Production Management 16 (7), 77–100.

Huang, G.Q., Mak, K.L., 2000. WeBid: A web-based framework to support early supplier involvement in new product development. Robotics and Computer Integrated Manufacturing 16, 169–179.

Humphreys, P.K., Lai, M.K., Sculli, D., 2001. An inter-organizational information system for supply chain management. International Journal of Production Economics 70, 245–255.

Jayaram, J., Shawnee, K.V., Droge, C., 2000. The effects of information system infrastructure and process improvements on supply-chain time performance. International Journal of Physical Distribution & Logistics Management 30 (3/4), 314–330.

Jutla, D., Bodorik, P., Dhaliwal, J., 2002. Supporting the e-business readiness of small and medium-sized enterprises: Approaches and metrics. Internet Research: Electronic Networking Applications and Policy 12 (2), 139–164.

Kalakota, R., Whinston, A.B., 1996. Frontiers of Electronic Commerce. Addison-Wesley, Reading, MA.

Kaplan, S., Sawhney, M., 2000. E-hubs: The new B2B marketplaces. Harvard Business Review (May–June), 97–103.

Kardaras, D., Karakostas, B., 1999. The use of fuzzy cognitive maps to stimulate the information systems strategic planning process. Information and Software Technology 41, 197–210.

Kehoe, D.F., Boughton, N.J., 2001. New paradigms in planning and control across manufacturing supply chains. International Journal of Operations & Production Management 21 (5/6), 582–593.

King, W.R., 1978. Strategic planning for management information systems. MIS Quarterly 2 (1), 23–37.

Klouwenberg, M.K., Koot, W.J.D., van Schik, J.A.M., 1995. Establishing business strategy with information technology. Information Management & Computer Security 3 (5), 8–20.

Kornelius, L., Wamelink, J.W.F., 1998. The virtual corporation: Learning from construction. Supply Chain Management: An International Journal 3 (4), 193–202.

Kuruppuarachchi, P.R., Mandal, P., Smith, R., 2002. IT project implementation strategies for effective changes: A critical review. Logistics Information Management 15 (2), 126–137.

Lambert, D.M., Cooper, M.C., Pagh, J.D., 1998. Supply chain management: Implementation issues and research opportunities. International Journal of Logistics Management 9 (2), 1–19.

Lancioni, R.A., Smith, M.F., Oliva, T.A., 2000. The role of the Internet in supply chain management. Industrial Marketing Research 29 (1), 54–65.

Lau, H.C.W., Lee, W.B., 2000. On a responsive supply chain information system. International Journal of Physical Distribution & Logistics 30 (7/8), 598–610.

Lauer, T.W., 2000. Side effects of mandatory EDI order processing in the automotive supply chain. Business Process Management Journal 6 (5), 366–375.

Lewis, I., Talalayevsky, A., 1997. Logistics and information technology: A coordination perspective. Journal of Business Logistics 18 (1), 141–157.

Lockamy, A., Smith, W.I., 1998. Strategic alignment approach for effective business process reengineering: Linking strategy, processes and customers for competitive advantage. International Journal of Production Economics 50, 141–153.

Love, P.E.D., 1996. Enablers of process reengineering. In: International Construction Information Technology Conference, Sydney, Australia, 18–19 April, pp. 77–84.

Maloni, M.J., Benton, W.C., 1997. Supply chain partnerships: Opportunities for operations research. European Journal of Operational Research 101, 419–429.

Mariotti, J.L., 1996. The Power of Partnerships–the Next Step Beyond TQM. Reengineering and Lean Production. Blackwell Publishers.

Marshall, P., McKay, J., 2000. Rethinking information systems planning in strategic business networks. In: Proceedings of the Americas Conference on Information Systems, p. 855.

Mason-Jones, R., Towill, D.R., 1997. Information enrichment designing the supply chain for competitive advantage. Supply Chain Management: An International Journal 2 (4), 137–148.

McCampbell, A.S., Clare, L.M., Gitters, S.H., 1999. Knowledge management: The new challenge for the 21st century. Journal of Knowledge Management 3 (3), 172–179.

McIvor, R., Humphreys, P., Huang, G., 2000. Electronic commerce: Re-engineering the buyer–supplier interface. Business Process Management Journal 6 (2), 122–138.

Min, H., Galle, W.P., 1999. Electronic commerce usage in business-to-business purchasing. International Journal of Operations & Production Management 19 (9), 909–921.

Motwani, J., Madan, M., Gunasekaran, A., 2000. Information technology in managing supply chains. Logistics Information Management 13 (5), 320–327.

Mukherji, A., Mukherji, J., 1998. Structuring organizations for the future: Analyzing and managing change. Management Decision 36 (4), 265–273.

Mullin, R., 1997. Putting the P in ERP. Chemical Week 159 (49), 149–151.

Murillo, L., 2001. Supply chain management and the international dissemination of e-commerce. Industrial Management & Data Systems 101 (7), 370–377.

Murray Jr., J., 1996. Electronic purchasing and purchasing law. Purchasing (February 15), 29–30.

Nah, F.F.-H., Lau, J.L.-S., Kuang, J., 2001. Critical factors for successful implementation of enterprise systems. Business process Management Journal 7 (3), 285–296.

Naylor, J.B., Naim, M.M., Berry, D., 1999. Leagility: Integrating the lean and agile manufacturing paradigms in the total supply chain. International Journal of Production Economics 62 (1–2), 109–118.

Overby, J.W., Min, S., 2001. International supply chain management in an Internet environment. International Marketing Review 18 (4), 392–420.

Pawar, K.S., Driva, H., 2000. Electronic trading in the supply chain: A holistic implementation framework. Logistics Information Management 13 (1), 21–32.

Perry, M., Sohal, A.S., 2000. Quick response practices and technologies in developing supply chains. International Journal of Physical Distribution Management and Logistics 30 (7), 627–639.

Philip, G., Pedersen, P., 1997. Inter-organizational information systems: Are organizations in Ireland deriving strategic benefits from EDI. International Journal of Information Management 17 (5), 337–357.

Porter, M.E., Millar, E., 1985. How information gives you competitive advantage. Harvard Business Review 63 (3), 149–160.

Ranchhod, A., Gurau, C., 1999. Internet-enabled distribution strategies. Journal of Information Technology 14, 333–346.

Reynolds, J., 2000. eCommerce: A critical review. International Journal of Retail & Distribution Management 28 (10), 417–444.

Roberts, B., Mackay, M., 1998. IT supporting supplier relationships: The role of electronic commerce. European Journal of Purchasing and Supply Management 4, 175–184.

Rockhart, J.F., Scott Morton, M.S., 1984. Implications of change in information technology for corporate strategy. Interfaces 14 (1), 84–95.

Rogerson, S., Fidler, C., 1994. Strategic information systems planning: Its adoption and use. Information Management & Computer Security 2 (1), 12–17.

Salcedo, A., Grackin, A., 2000. The e-value chain. Supply Chain Management Review 3 (4), 63–70.

Sambasivarao, K.V., Deshmukh, S.G., 1995. Selection and implementation of advanced manufacturing technologies. International Journal of Operations & Production Management 15 (10), 43–62.

Sarkis, J., Sundararaj, R.P., 2002. Evolution of brokering paradigms in e-commerce enabled manufacturing. International Journal of Production Economics 75, 21–31.

Scott, G.J., 1996. Expanding the role of the project director as the CIO in the information technology industry. Project Management Journal (September), 5–15.

Sharma, S., Gupta, J.N.D., 2002. Application service providers: Issues and challenges. Logistics Information Management 15 (3), 160–169.

Simchi-Levi, D., Kaminsky, P., Simchi-Levi, E., 2000. Designing and Managing the Supply Chain: Concepts, Strategies and Case Studies. McGraw-Hill International Edition, Singapore.

Skyrme, D., 1996. Networking to a better future–management insights. Available from <http://www.hiway.co.uk/skyrme/insights/insights.html>.

Spekman, R.E., Spear, J., Kamauff, J., 2002. Supply chain competency: Learning as a key component. Supply Chain Management: An International Journal 7 (1), 41–55.

Srinivasan, K., Kekre, S., Mukhopadhyay, T., 1994. Impact of electronic data interchange technology on JIT shipments. Management Science 40, 1291–1304.

Talluri, S., 2000. An IT/IS acquisition and justification model for supply-chain management. International Journal of Physical Distribution and Logistics Management 30 (3/4), 221–237.

Tan, K.C., 2001. A framework of supply chain management literature. European Journal of Purchasing & Supply Management 7, 39–48.

Teo, T.S.H., Ang, J.S.K., 1999. Critical success factors in the alignment of IS plans with business plans. International Journal of Information Management 19, 173–185.

Tollington, T., Wachter, P., 2001. ABC/TA Internet retail shopping. International Journal of Retail & Distribution Management 29 (4), 149–155.

Tracey, M., Smith-Doerflein, K.A., 2001. Supply chain management: What training professionals need to know. Industrial and Commercial Training 33 (3), 99–104.

Turowski, K., 2002. Agent-based e-commerce in case of mass customization. International Journal of Production Economics 75 (1–2), 69–81.

van Hoek, R., 2001. E-supply chains—virtually non-existing. Supply Chain Management: An International Journal 6 (1), 21–28.

van Hoek, R.I., Chong, I., 2001. Epilogue: UPS logistics—practical approaches to the e-supply chain. International Journal of Physical Distribution & Logistics Management 31 (6), 463–468.

van Hooft, F.P.C., Stegwee, R.A., 2001. E-business strategy: How to benefit from a hype. Logistics Information Management 14 (1/2), 44–53.

Verwijmeren, M., van der Vlist, P., van Donselaar, K., 1996. Networked inventory management information systems: Materializing supply chain management. International Journal of Physical Distribution and Logistics Management 26 (6), 16–31.

Voss, H., 1996. Virtual organizations: The future is now. Strategy & Leadership 24 (4), 12–18.

Walsh, P., Koumpis, A., 1998. Introducing the concept of information supply chains: The buddy project. Journal of Logistics Information Management 11 (2), 74–79.

Walsh, P., Barziv, O., Koumpis, A., 2000. Managing real time interactions in industrial environments based on informa-

tion supply chains; the ESPRIT ATLAS project. Logistics Information Management 13 (2), 94–102.
Walton, S., Gupta, N.D., 1999. Electronic data interchange for process change in an integrated supply chain. International Journal of Operations & Production Management 19 (4), 372–388.
Wang, S., 2000. Managing the organizational aspects of electronic commerce. Human Systems Management 19, 49–59.
Warkentin, M., Bapna, R., Sugumaran, V., 2000. The role of mass customization in enhancing supply chain relationship in B2C e-commerce markets. Journal of Electronic Commerce Research 1 (2), 1–17.
Warkentin, M., Sugumaran, V., Bapna, R., 2001. E-knowledge networks for inter-organizational collaborative e-business. Logistics Information Management 14 (1/2), 149–162.
Watson, R.T., Akelsen, S., Pitt, L.F., 1998. Building mountains in that flat landscape of the World Wide Web. California Management Review, 36–56.
Webster, J., 1995. Networks of collaboration or conflict. Electronic data interchange and power in the supply chain. The Journal of Strategic Information Systems 4 (1), 31–45.
Werbach, K., 2000. Syndication: The merging model for business in the Internet era. Harvard Business Review (May–June), 85–93.
Williams, L.T., 1997. Planning and managing the information system—a manager's guide. Industrial Management & Data Systems 97 (5), 187–191.
Williams, L.R., Magee, G.D., Suzuki, Y., 1998. A multidimensional view of EDI; testing the value of EDI participation to firms. Journal of Business Logistics 19 (2), 73–87.
Williford, J., Chang, A., 1999. Modelling the FedEx IT division: A system dynamics approach to strategic IT planning. The Journal of Systems and Software 46, 203–211.
Wilson, T.P., Clarke, W.R., 1998. Food safety and trace ability in the agricultural supply chain: Using the Internet to deliver traceability. Supply Chain Management 3 (3), 127–133.
Yamaya, E., Wendy, C., Seltsikas, P., 2002. Delivering enterprise resource planning systems through application service providers. Logistics Information Management 15 (3), 192–203.
Yu, Z., Yan, H., Cheng, T.C.E., 2001. Benefits of information sharing with supply chain partnerships. Industrial Management & Data Systems 101 (3), 114–119.
Zimmerman, C., 2000. Partnership are vital to Sears' Web strategy. Internet Week (12 June), 77–80.
Zsidism, G.A., Jun, M., Adams, L.L., 2000. The relationship between information technology and service quality in the dual-direction supply chain: A case study approach. International Journal of Service Industry Management 11 (4), 312–328.