Assimilation and Diffusion of Web Technologies in Supply-Chain Management: An Examination of Key Drivers and Performance Impacts

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ABSTRACT: A key reason for the popularity of integrated supply-chain management (SCM) is that Web technologies have made supply-chain coordination a viable managerial and strategic option. Building on research in the areas of management information science, supply chains, and organizational innovation, this study explores the use of Web technologies for organizational SCM. Based on an extensive survey of North American organizations, it investigates the assimilation of Web technology systems into internal supply-chain functions and their external diffusion into interorganizational supply-chain networks, and also explores the relevant environmental determinants. The findings suggest that internal assimilation and external diffusion of Web technologies both significantly affect the benefits realized by SCM. Supplier interdependence and information technology (IT) intensity are important environmental factors affecting external diffusion. Organizational factors, such as centralization and formalization of the IT unit structure and high levels of managerial IT knowledge, are significant drivers of Web technology assimilation in the SCM function.

KEY WORDS AND PHRASES: e-business, information technology value, supply-chain management, technology assimilation, technology diffusion, Web technologies.

After only a few years of commercial usage, the Internet has revolutionized the way organizations conduct their businesses. The emergence of the Internet and Web technologies has provided an opportunity for many firms to move toward an extended enterprise business model—one that enhances value along the total supply chain [52, 59, 61, 87]. Dell, General Electric, Cisco, Ford, and other companies have claimed significant benefits through the use of Web applications in their supply-chain management (SCM) function [2, 9, 59].

SCM encompasses a range of activities, such as purchasing, materials handling, production planning and control, warehousing, logistics, inventory management, distribution, delivery, and vendor management. The primary objectives of the SCM function include cost reduction, service improvement, improved communication and interaction among supply-chain partners, and increased flexibility in terms of delivery and response times. Internet and Web technologies have presented firms with significant opportunities in the forms of efficient and timely order fulfillment, reduced cycle times, electronic payments, e-procurement, and more for improving their supply-chain performance. Thus, it is not surprising that more firms are deploying Web-based
business-to-business (B2B) SCM systems, especially in the areas of e-procurement and e-sourcing [37]. Firms are taking initiatives of many kinds, such as building their own Web-based supply-chain systems, developing private marketplaces (e.g., WalMart’s RetailLink and GE’s Global Exchange), joining industry-oriented B2B exchanges (e.g., Transora.com), or joining the B2B hubs of other third parties (e.g., VerticalNet). B2B e-commerce initiatives resulted in a market that was worth $433 billion in 2000 and, according to the Gartner Group, will grow to $6 trillion by the end of 2004 [67]. Jupiter Communications forecasts that $6.3 trillion worth of interfirm trade will take place over the Web by 2005. Although the benefits of Web technologies in the SCM function are well acknowledged, the implementation of Web technologies and systems is challenging. Successful deployment of Web applications requires smooth integration of a number of organizational, functional, and technological factors [17]. In the SCM context, the success of a Web-based system is largely contingent upon the extent to which the system is assimilated internally and diffused among networks of business partners in a supply chain. Given these challenges in deploying Web-based SCM systems, several questions remain unanswered: Is the use of Web-based SCM systems an improvement over traditional electronic data interchange (EDI) systems for interorganizational coordination? What benefits are realized by deploying e-business systems in supply chains? How can organizations effectively diffuse and assimilate Web technologies in their SCM function? What managerial mechanisms are required for successful deployment of Web systems in the SCM function?

The overarching theme of the present research is to gain an understanding of the effective deployment of Web technologies in the organizational SCM function. The objective is to develop an empirical understanding of the factors affecting the assimilation and diffusion of Web technologies in the SCM function, and to assess the benefits of deploying Web technologies in supply chains. Assimilation refers to the extent to which the use of technology permeates organizational work processes and activities [3, 17, 20, 30]. Diffusion refers to the degree to which the use of technology crosses organizational boundaries into the activities of external business partners [30]. It focuses on the extent to which suppliers and other business partners accept and adopt a firm’s technologies and systems to conduct interfirm transactions. The benefits of deploying Web technologies and systems are contingent upon the extent to which a firm internally assimilates these technologies in its internal supplier-oriented activities as well as the degree to which Web technologies are externally diffused into supply-chain interactions and transactions. The following specific research questions are addressed:

- Do Web technologies and systems create any significant value in the SCM function?
- How do the assimilation and diffusion of Web technologies affect the benefits realized from deploying these technologies in the SCM function?
- What are the key factors that affect the external diffusion of Web technologies and systems in the SCM function?
What are the key factors that affect the internal assimilation of Web technologies and systems in the SCM function?

In contrast to the considerable amount of research effort in the area of traditional information technology (IT) systems, including interorganizational systems (IOS) and EDI, there has been little empirical research on Web technologies and systems, especially in interorganizational settings. Web-based systems are fundamentally different from traditional EDI systems, which were based primarily on the idea of locking in customers and suppliers, and thereby led to higher switching costs. Web technologies and systems, relatively inexpensive and highly flexible, have greatly reduced the switching costs of suppliers and customers [78]. This makes it important to examine whether our knowledge of interorganizational and EDI systems extends to the context of Web systems. Given the increased usage of Web-based SCM systems, it is also necessary to ascertain the true impact of these systems, and to identify the factors that facilitate their assimilation and diffusion.

Although the literature on operations management is replete with studies of the strategic and managerial aspects of SCM, it offers little on the application of Web technologies in SCM. The information systems (IS) literature on the usage and impact of Web technologies in the supply-chain function is also limited. This paper addresses these gaps by examining the factors affecting the assimilation and diffusion of Web technologies in supply chains and the ultimate benefits of Web-based SCM systems.

Theoretical Background and Research Model

Two streams of research form the theoretical background for this study: the notion of extended enterprise, used to understand the role of Web technologies in the supply-chain management function [24], and innovation diffusion theory [90], widely applied in several areas, including IT adoption and diffusion. These are supplemented by material drawn from the literature on IOS, EDI, and e-business technologies and applications, and from the literature on operations and SCM.

Innovation diffusion theory provides concepts and tools that aid in studying technology evaluation, adoption, and implementation [90]. A number of scholars have used innovation diffusion theory to examine the likelihood and extent of technology adoption, assimilation, and diffusion in organizations [29, 30, 81]. The theory has also been used to identify the many factors that facilitate or inhibit technology adoption and implementation [39, 40, 79, 80]. The present paper draws upon the rich literature on innovation diffusion and IT adoption and diffusion to understand how Web technologies are internally assimilated into an organization and externally diffused into its supplier networks. According to innovation researchers, several characteristics of an organization and its environment affect the rate of technology assimilation and diffusion. The focus here is on identifying some of the key factors in the specific context of Web technologies and their assimilation and diffusion in the supply-chain function.
Web Technologies and Extended Enterprise

The concept of the extended enterprise is relatively new, and there is considerable research in progress. Extended enterprise calls for cooperation and tight integration of firms and their supply-chain partners, as opposed to discrete, independent, and isolated activities across the supply chain [24]. The extended enterprise concept builds on the SCM approach by seeing all the members and partners of a value network as working toward a common goal or opportunity. A key aspect is the integration of the value chains of the various supply-chain partners into the organization’s internal value chain to yield new value configurations [94]. Web technologies as well as traditional ITs have had a fundamental impact on interfirm buyer-supplier relationships. Some of the best-known success stories in airlines, hospital supplies, finance, and other industries in the mid-1980s and 1990s were rooted in IT-enabled interorganizational arrangements [48]. Thus, one can hardly doubt the potential role of ITs in influencing, enhancing, and extending interfirm buyer-supplier electronic relationships.

Given the enhanced capabilities offered by Web technologies and the relative cost advantages of Web systems, many firms are deploying Web-based supply-chain applications. For example, through the Cisco supplier connection (CSC), suppliers have access to Cisco’s enterprise resource planning (ERP) order-fulfillment systems and inventory databases, and so can respond to customer requests in real time. Cisco is able to track and transfer inventory between different manufacturers to respond to component shortages [56]. El-Sawy makes the case that just as business process reengineering (BPR) was used as the managerial trigger for radically changing internal business processes using new technology in the early 1990s, it is now imperative for organizations to radically redesign their interorganizational supply chains using Web technology [27]. To this end, he presents a methodology that incorporates supply-chain redesign principles and an interorganizational workflow modeling tool. Firms that wish to become extended enterprises through the deployment of Web-based supply-chain solutions must assimilate the technology internally and diffuse it among their supplier networks.

At present, the evidence about the performance impact of Web-based supply-chain systems is only anecdotal. Performance impact can usually be measured in terms of cost and time savings [36]. For example, using the Web for SCM has enabled Cisco to reduce its operating costs by $75 million, and 45 percent of the products it sells are untouched by Cisco—they are shipped directly from suppliers to customers [56]. Similarly, Dell has used virtual integration of its supply chain to reduce its inventory to 11 days, compared to 90 days for its competitors. As a result, Dell can offer its customers the latest technology at competitive prices, because the cost of carrying obsolete inventory is reduced through rapid inventory turnover [64]. Despite the benefits reported in anecdotal case studies, there is considerable ambiguity about the value generated through such e-business applications, and about the relationship between assimilation, diffusion of Web technologies, and the benefits realized.
Development of Research Model

The assimilation and diffusion of information technology in organizations has been of great interest to researchers on information systems for more than a decade. Earlier studies did not differentiate internal assimilation and external diffusion. Instead they used the term “diffusion” to represent the multiple stages through which IT pervades organizational routines and processes. Most studies emphasized a three-stage model of IT diffusion—initiation, adoption, and diffusion—based on the classic innovation diffusion model proposed by Rogers [90] and subsequently adapted to organizational theory, organizational design, and individual, functional, and firm-level studies on innovation. The three-stage model has been refined in IS research to more broadly conceptualize the diffusion process, with substages of adaptation, acceptance, routinization, and infusion [20]. Several studies view IT diffusion as an internal permeation process extending from initial awareness to full institutionalization within the firm [20, 30, 70], but a broader notion of the diffusion process has been adopted in some research on the interorganizational use of IT. In several instances, researchers on interorganizational systems and EDI have differentiated internal and external diffusion, concentrating on the permeation of the diffusion process in the extended value chain of a firm [46, 81, 83]. The present paper is focused on the SCM function, which encompasses a range of internal organizational activities as well as interorganizational processes that stretch beyond firm boundaries. In line with earlier research on IOS/EDI researchers, it treats both internal assimilation and external diffusion.

The discussion in this paper operationally defines internal assimilation as the extent to which Web technologies and applications are used in key internal organizational activities in the SCM function. External diffusion refers to the extent to which the firm has integrated its supply-chain partners by using Web technologies and systems to perform transactions with them. Assimilation and diffusion, taken together, represent the infusion stage in the process of innovation diffusion [81, 83]. Once it has adopted and adapted a technology, a firm begins to use technology in a comprehensive and integrated manner to support organizational work and transfers of technology both inside and outside the organization. Internal assimilation and external diffusion together constitute the “infusion” stage in the overall diffusion process. Many researchers have examined assimilation or diffusion separately [3, 17, 30, 82], but very few studies have examined the constructs together [81, 83]. The studies that examine both assimilation and diffusion treat them similarly, proposing identical antecedents for the two constructs. However, the results show that the factors that affect internal assimilation are not the same as the ones that affect external diffusion among business partners [81, 83]. For instance, the relative advantage of EDI, as perceived by the firm, was its influence on internal assimilation (but not diffusion), and the technical compatibility of EDI was found to influence external diffusion only [81, 83]. Note that these studies do not focus on the interrelationships between assimilation and diffusion. The present research, in contrast, examines both these constructs and explores the nature of the association between them.
Electronic B2B linkages among firms and suppliers have traditionally been established using EDI via a value-added network. Because EDI systems are proprietary and costly, smaller firms tend not to use them. The advent of user-friendly Web browsers in the early 1990s gave rise to Internet-enabled EDI and B2B systems that are affordable, even for smaller firms. The benefits of EDI include quick response time, lower personnel costs, shorter purchase lead-time, greater accuracy, and improved customer service [81]. In addition, Web-enabled SCM offers several other advantages, such as ease of implementation, platform independence, new marketing and sales channels, demand-management capabilities, supplier-support capabilities, easy-to-use interfaces, and track-and-trace functionality.

A key objective of SCM is the creation, maintenance, and real-time optimization of an integrated and seamless supply chain for products and services across functional and interorganizational boundaries through the integrated management and synchronization of physical, information, and financial flows [2]. A central theme underlying SCM involves integration and collaboration in operational planning and execution, in relation to internal logistics functions (e.g., inventory management, production planning, cycle time reduction, warehousing) and external supply-chain functions (e.g., distribution network coordination, transportation planning, integrated purchasing portals, interorganizational or market-based coordination in reverse logistics, post-sales customer service, technical support) [87]. The use of ERP systems for integrating internal manufacturing and logistics functions marked the first stage of IT-based SCM in organizations. The introduction of the Internet revitalized and accelerated this trend, because it facilitated a second stage of Web-based SCM in organizations. This stage focused on the external deployment of Web technology for SCM applications, such as inventory synchronization, creating B2B marketplaces, building aggregation portals, and building relationships. The idea behind such initiatives was to promote the participation of suppliers in interfirm transactions and to enhance the digital integration of firms and their suppliers. The use of Web technologies and systems in SCM provides an opportunity to realize efficiencies and cost-related benefits that improve internal information sharing and processing. It also affords opportunities to improve business processes through synchronized information exchange between firms and their supply-chain partners [49].

The assimilation and diffusion of Web technologies in a supply-chain function are critically dependent on the external and internal organizational environments. A set of factors likely to affect the assimilation and diffusion of Web technologies in SCM was compiled by means of a literature review. The intent here is to identify and examine a set of critical factors rather than to comprehensively list every potential predictor of Web technology assimilation and diffusion in SCM. The review of the literature on IT diffusion, IOS, EDI, operations management, and SCM (see Table 1), identified the following key factors:

1. supplier interdependence
2. competitive intensity
3. IT activity intensity
4. managerial IT knowledge
The first three factors pertain to the external environment of the firm, and the other three belong to the internal organizational environment. Research indicates that internal factors are salient in respect to internal assimilation, and external factors are dominant in diffusion [81, 83, 96]. Three factors from the organizational environment (managerial IT knowledge, centralization, and formalization) are expected to be associated with internal assimilation of Web technologies and systems. The three factors pertaining to the external environment (supplier interdependence, competitive intensity, and IT activity intensity) are expected to be associated with the external diffusion of Web technologies and systems in SCM. Fichman’s comprehensive review of IT diffusion research notes the significant roles of external environmental factors and internal organizational factors in IT diffusion and assimilation [29]. The present paper argues that internal assimilation and external diffusion both enhance the benefits of deploying Web systems in SCM. The overall conceptual model, with the research constructs and proposed relationships, is presented in Figure 1.

Supplier Interdependence

According to the resource-dependency perspective, organizations are dependent on their environment for resources, and these dependencies constrain organizational activities [76]. Firms gain access to needed resources by establishing relationships with other organizations, such as suppliers and other partners. The resource-dependence theory emphasizes the power relationships and interdependencies between firms and other entities in the environment that influence their managerial activities. Research on SCM has identified supplier interdependence as an important factor in the formation of supply-chain partnerships [21, 69, 73]. Because IT systems, such as EDI, interorganizational, and B2B systems, promote electronic partnerships across the entire supply chain, supplier interdependence is likely to affect a firm or its supplier’s decision to use interorganizational Web systems.

A supplier’s decision to use a firm’s Web-based system will depend on the interdependence of the firm and the supplier. Firms tend to use persuasive or
coercive power to influence suppliers to adopt EDI systems [44]. Persuasive tools include educating partners about benefits and helping them to adopt, deploy, and implement systems. Coercive techniques include forcing partners to adopt a technology or system, and threatening to drop them if they refuse to do so. EDI and some of the earlier systems often required a proprietary standard for formatting and exchanging information. This limited the flexibility of suppliers to establish electronic linkages with other partners. With the advent of open standards and flexible Web technologies that are platform and technology independent, however, it is now easy to establish multiple partnerships or even switch partnerships [57, 78]. Firms and supplies that are highly interdependent must work jointly to establish electronic linkages via the Web. The interdependence of firm and suppliers influences the deployment of IOS and EDI [16, 44, 80]. The more interdependent a firm and its suppliers are, the more the firm should strive to diffuse its Web systems in its supply chain. A firm with higher levels of supplier interdependence will go to greater lengths to make its suppliers accept its Web systems and trade with it electronically so as to improve the efficiencies of its supplier-related operations.
H1: The greater the interdependence between a firm and its suppliers, the greater will be the external diffusion of Web technologies in SCM.

Competitive Intensity

Competitive pressure is an important variable influencing the deployment and diffusion of IS [39, 46, 89]. Firms initiating IOS and EDI derive considerable benefits compared to those that follow [86, 88]. As a result, there is considerable pressure on firms to initiate such systems and diffuse them among their partners before their rivals do so. This pressure sometimes leads to the use of coercive tactics to diffuse the systems among suppliers.

Firms that are first-movers in deploying IOS tend to derive more advantage. Thus, there is significant pressure for them to diffuse systems quickly, both internally and externally, in order to realize this gain. Peer pressure from industry and other competitors may also force firms to deploy Web-based applications faster. The fact that the value of B2B supplier networks and marketplaces is a function of the critical mass of participating partners increases the pressure on firms in competitive settings to introduce SCM applications before their competitors [91]. Firms in intensely competitive environments are likely to expend considerable effort in diffusing Web systems to suppliers so as to strengthen the integration with suppliers that could give them a competitive advantage.

H2: The greater the competitive intensity facing a firm, the greater will be the external diffusion of Web technologies in its SCM.

IT Activity Intensity in Industry

IT activity intensity refers to the extent to which a firm’s partners, suppliers, customers, and competitors adopt and deploy IT in their business processes and activities [84]. IT activity intensity represents the level of IT use by a network of industry players. The amount of IT use by customers and suppliers influences an organization’s IT activities and IT usage [11]. Bouchard states that an organization’s decision on EDI “is primarily based on what [its] business partners are doing, and not on the characteristics of EDI” [8, p. 366]. Higher levels of IT activity intensity in an industry imply IT-savvy suppliers and business partners. Under conditions of IT activity intensity, suppliers will more readily accept Web systems for conducting interfirm business transactions. Higher levels of IT activity intensity in an industry imply better IT infrastructure and applications in the supplier firms that could facilitate easier diffusion of new e-business systems. Iskander, Kurokawa, and LeBlanc found that IT-savvy suppliers had better technical capabilities to easily adopt, integrate, and use EDI systems [47]. Therefore, the more industry players deploy and use information technologies, the greater will be the firm’s ability to diffuse Web technologies and systems in its SCM activities.
H3: The greater the IT activity intensity in the industry, the greater will be the external diffusion of Web technologies in SCM.

Managerial IT Knowledge

Managerial IT knowledge refers to the union of IT-related and business-related knowledge possessed and exchanged by IT executives, top managers, and functional managers [11]. It is a conjunction of (a) top management’s tacit knowledge of the strategic potential of IT, (b) functional management’s knowledge of IT, and (c) the business-related knowledge of IT executives and personnel. The need for top managers and functional managers to understand and value IT in order for IT to succeed is well understood and documented. An effective alignment of IT and business objectives can only be achieved if the CIO and the senior IT executives have a good knowledge of the business domains in which the firm operates [4].

Boynton, Zmud, and Jacobs suggest that only an amalgamation of IT and business knowledge can lead to effective technology diffusion [11]. Armstrong and Sambamurthy found evidence that senior management’s IT knowledge has a positive impact on the extent of IT assimilation [3]. They emphasize the importance of creating mechanisms and structures to enhance the development of managerial IT knowledge in organizations. Applying a resource-based view of firms, Mata, Fuerst, and Barney identified managerial IT knowledge as a critical capability in the successful deployment of systems for gaining strategic benefits [66]. Chatterjee, Grewal, and Sambamurthy found senior management leadership to be an important factor in the organizational assimilation of Web technologies [17]. In another study, Purvis, Sambamurthy, and Zmud found managerial IT knowledge to be an effective enabler of IT assimilation [82]. For a firm to assimilate and deploy Web technologies into its supply-chain activities, it is important that the senior leadership, the functional managers responsible for SCM activities, and the IT managers have a good understanding of Web technologies and of the strategic impact of Web technologies on the SCM function.

H4: Higher levels of managerial IT knowledge will be positively associated with greater assimilation of Web technologies in SCM.

IT Unit Structure

The structural perspective on organizations maintains that structural mechanisms are at the core of organizational design [42, 51, 71]. In the IS context, the structure of the IT unit is an important factor in the process of technology assimilation. Several researchers have investigated the design of effective IT unit structures [1, 12, 107]. Centralization and formalization are often cited as key elements in IT unit structure [20, 85]. Centralization of IT unit structure refers to the extent to which the key decision responsibilities for IT activities reside with the IT unit, as opposed to
the functional business units of the organization [13]. Research on IT adoption and diffusion indicates that centralized structures inhibit the organizational adoption and diffusion of technologies. Grover and Goslar, in a study of the assimilation of telecommunication technologies, found that there was a negative relation between centralization and the adoption and implementation of technologies [40]. In another study, Grover found that centralization significantly inhibited the adoption of customer-based IOS [39]. In light of this, decentralized structures and cross-functional coordination mechanisms are often suggested as ways to ease the IT assimilation process [1, 98]. In the context of e-commerce, Earl and Khan suggested the use of multidisciplinary, cross-functional teams to manage e-business efforts [25]. Chatterjee, Grewal, and Sambamurthy found a positive association between coordination across IT and other business units, and Web technology assimilation [17].

The literature on operations management also points to the significance of decentralized structures. According to Bowersox and Daugherty, firms with decentralized, flatter structures are likely to adopt innovative technologies to improve organizational communication and coordination both internally and with supply-chain partners [10]. Germain, Drodge, and Daugherty found that decentralization significantly influenced decisions on integrative technologies [38]. Williams, Magee, and Suzuki found a negative, although insignificant, relation between centralization and few dimensions of EDI participation [100]. IT and SCM activities under centralized IT unit structures tend to involve less participation by logistics and SCM managers as well as by external suppliers. Operations, purchasing, and SCM executives are likely to possess greater knowledge about supply-chain processes, and their cooperation and interaction are important if the Web system is to be assimilated within the key organizational routines. Therefore,

H5: Centralization of an IT unit structure will be negatively associated with the assimilation of Web technologies in SCM.

Formalization refers to the extent of reliance on formal rules, procedures, and task committees for carrying out activities in an organization [39]. Formalization of IT unit structure focuses on the use of formal systems, operating procedures, and structural devices, such as teams, committees, and task forces, in IT-related processes and activities. Despite its negative associations with initiation/adoption [39, 41, 106], formalization is a positive facilitator for organizational technology assimilation [19, 58, 106]. Germain, Drodge, and Daugherty found that formalization was a positive predictor of assimilation of logistics technologies [38]. Researchers on organizational innovation have documented the positive impact of formal structures on innovative behavior in organizations [92]. The use of formal mechanisms is especially important in the context of implementing a Web-based SCM system, because it spans across organizational boundaries and involves active participation by suppliers. A well-documented procedure for developing and deploying an IT system will facilitate the diffusion of the system among supplier networks. Some firms rely on formal contractual agreements for implementing and diffusing EDI and Web-based SCM systems. Common industry practice also involves the
use of formal joint teams and task forces to oversee Web project implementations [25].

H6: Formalization of IT unit structure will be positively associated with the assimilation of Web technologies in SCM.

Assimilation and Diffusion of Web Technologies

Assimilation and diffusion are distinct, yet closely interrelated, constructs in IS research [29]. These constructs assume greater importance in the case of interorganizational technologies that involve two or more organizations. The importance of these constructs is recognized in IOS and EDI research, but the association between assimilation and diffusion has not yet been thoroughly explored.

In a case study of Web-based procurement in a heavy equipment manufacturing firm, Chandrasekar and Shaw suggested that the benefits from the deployment of a Web-based procurement system would be low unless the e-procurement system was diffused to a larger set of suppliers [14]. Similarly, Premkumar and Ramamurthy suggested that linking EDI with one supplier/customer might be insufficient to justify the investments in EDI [79]. Therefore, firms should expand their linkages to other trading partners to justify the cost and increase the savings. The efficiencies and benefits derived from initially using EDI with a single customer/supplier could motivate a firm to expand its scope to include other trading partners, thereby facilitating external diffusion [81].

Researchers have observed that interorganizational systems (e.g., EDI, Web technologies) may become strategic necessities as their use increases [7, 68, 105]. Some firms may be motivated to adopt such systems as an essential part of doing business, and this will facilitate external diffusion. Other firms may try to retain competitive advantage by expanding their IOS network to include other trading partners, thereby lowering costs and increasing benefits through leveraging the system across multiple partners.

According to Champy, business reengineering tends to be applied within an organization to reduce cost and increase speed and productivity, whereas the concept of X-engineering argues that organizations must extend their processes outside the firm and form electronic linkages across organizational boundaries [15]. Such linkages would be greatly facilitated by the use of Web technologies among business partners. Bovet and Martha suggested, along the same lines, that value net—a dynamic, high-performance network of customer/supplier partnerships and information flow—exemplifies the business design of successful firms like Dell and Cisco, which use Web technologies to streamline their supply chains [9]. It follows that internal assimilation of Web technologies within a firm is likely to be positively associated with external diffusion outside the firm in order to create a value network that leverages Web technologies more effectively for the common benefit of partners linked to the network.
H7: Internal assimilation of Web technologies will be positively associated with the external diffusion of Web technologies in SCM.

Performance Impact of the Assimilation and Diffusion of Web Technologies

The performance impact of IT has generated considerable interest. Researchers have investigated the returns on IT investments at the national, industry, and firm levels, and the relationship between IT usage and business performance [6, 22, 55, 63]. Although the findings on the performance impact of IT are mixed, recent research suggests that systems usage is an important variable that can explain the value generated from IT [23]. The importance of systems usage has been pointed out by several researchers [44, 65]. Consistent with these ideas, the present research examines the link between Web systems usage in SCM and the benefits of using Web systems in SCM.

One of the questions asked in the present research relates to the value and benefits of the use of Web technologies and applications in SCM. The specific interest lies in examining whether the use of Web technology applications (theoretically defined in terms of assimilation and diffusion) is related to the performance impacts in SCM. The performance impacts of Web technologies are captured through the benefits realized by utilizing these technologies in SCM. This is in line with the goals- and benefits-based approach to performance measurement that is discussed in the SCM literature [74]. The internal assimilation and external diffusion of Web technologies into SCM serve as indicators of IT/systems usage, that is, the level of use of Web technologies in the SCM activities of the firm. In some instances, firms that have installed, commissioned, and used Web applications have reported little or insignificant gain from the use of Web technologies [78]. This makes it critical to examine the association between Web technology usage and the benefits realized.

Research on IOS and EDI has identified significant organizational impacts due to assimilation and diffusion of interorganizational systems. Iacovou, Benbasat, and Dexter found that performance impacts were enhanced by increased usage of EDI [46]. Lee, Clark, and Tam found significant performance improvements as a result of EDI-enabled supply-chain reengineering in grocery retail chain firms [60]. Chatfield and Yetton analyzed three case studies of EDI implementation; they found that the extent of EDI usage by EDI initiator firms and their partners is a key determinant of the strategic payoffs from EDI [16]. Yao, Palmer, and Dresner reported significant improvements in supply-chain performance with the use of electronic systems, such as EDI and the Internet [104]. Ramamurthy and Premkumar found that greater assimilation and diffusion of EDI facilitated improved organizational performance [83]. They concluded, “In order to be able to truly exploit the large scale operational and strategic benefits potential that is latent in EDI, the adopter firm will need to systematically plan and pursue more extensive internal and external diffusion of EDI.”

Research in operations management also indicates that Web systems have
a strong impact on the SCM function [59]. Frohlich and Westbrook proposed a four-level model for Web-based integration between a firm and its suppliers and examined the linkages between Web-based integration and the benefits in terms of firm performance [35]. The four levels of Web-based integration varied on two key dimensions: degree of Internet-based supply integration and degree of Internet-based demand integration. The four levels represented different points on a continuum. At one end of the continuum are firms that have little or no Web-based integration with suppliers. At the other end is complete Web-based integration, where the whole supply chain, from end-customers to suppliers, is digitized. In between these polarities are firms that partially digitize their supply chain—they Web-integrate either with their suppliers or with business-customers. Based on survey data obtained from senior operations executives, the study found that higher levels of performance were associated with higher levels of Web-based integration. In a related study, Frohlich found a positive connection between e-integration in supply chain and performance [34]. In other words, firms that used Web technologies to integrate more with their suppliers reaped greater performance benefits than firms that had relatively lower levels of Web technology usage in their supply chains. Hence, one may anticipate a positive relationship between Web-technology assimilation/diffusion in SCM and the benefits accruing from it.

H8: The greater the internal assimilation of Web technologies in SCM, the greater will be the benefits realized from it.

H9: The greater the external diffusion of Web technologies in SCM, the greater will be the benefits realized from it.

Research Methodology and Data Analysis

Measures

Most of the constructs in this study are measures from the literature that were adapted to the context of the study. Multiple-item measures were used to assess the research constructs. All the items were measured using a 7-point Likert-like scale. The content validity of the measures was assessed by pretests with knowledgeable experts and IT managers.

The items for measuring assimilation tapped the extent to which Web technologies and applications were used in internal supply-chain activities. Assimilation was assessed by asking respondents about the extent to which they used Web technologies and applications in five internal SCM activities: (a) supplier selection (getting quotes, bids, etc.), (b) purchase-order processing, (c) procurement from suppliers (distribution, warehousing, logistics, etc.), (d) invoicing and payment processing, and (e) demand management and procurement analysis. The initial set of activities was derived from the literature on SCM and was refined and validated by the pilot tests [26, 93, 95, 101].

External diffusion was measured using three items that asked respondents to indicate how many suppliers they had interacted with using Web technologies, total supplier transactions done using Web applications, and overall sup-
Supplier interactions handled through Web applications. These items were adapted from Premkumar, Ramamurthy, Nilakata [81] and Ramamurthy and Premkumar [83].

Supplier interdependence was measured using four items adapted from Premkumar and Ramamurthy [79]. These items measure a firm's dependence on its suppliers and the reciprocal dependence of suppliers on the firm. The measurement was based on responding firms’ perceptions of their interdependence with their suppliers.

These items capturing the competitive intensity construct were derived from Germain, Drodge, and Daugherty [38]. These assessed the perceptions of the responding firm on the extent to which it monitors and keeps track of competitors in the industry. IT activity intensity was measured using four items obtained from Purvis, Sambamurthy, and Zmud [82]. These focused on the extent of IT usage and levels of IT-related activities among suppliers, customers, competitors, and other business partners.

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It was then pretested with eight senior IT managers who had considerable experience in e-commerce system deployment. During interviews with these senior IT managers, their feedback was obtained on the questionnaire after they had completed the survey. Refinements were made at each stage based on the feedback from the pilot-test respondents.
Table 2. Measurement Model Loadings.
Method and Sample

A field survey method was adopted for the study. An initial sampling frame was assembled from the ACR directory of top computer executives in North America and from senior IT executives of organizations listed on the Toronto Stock Exchange’s Listed Company Directory. From these sources, 1,200 organizations with more than 500 employees and at least 20 IT personnel were randomly selected. The target respondent in each firm was the highest-ranking IT executive, often the CIO. The initial survey in the summer of 2001 was followed by two reminders. The questionnaire and reminders produced 249 responses, a response rate of 20.75 percent, which is comparable to similar studies [39, 40, 83]. Because the research was focused on the assimilation, diffusion, and performance impacts of Web technology deployment in SCM, only firms that had already implemented Web technologies in the supply chain were included in the final analysis. Of the 249 respondent firms, 176 had deployed Web technologies in supplier-related activities. In line with the research goals, only these responses were considered in the final analysis.

Table 3 presents the demographic profiles of the respondent firms. The sample had a heterogeneous representation in terms of industry categories. The firms in the sample were fairly distributed across different industry groups in manufacturing and service-related sectors. About two-thirds had annual revenues in excess of $50 million. Because the research sought to assess the benefits of Web technology deployment in SCM, data were obtained about the period in which the firm deployed it. As shown in Table 3, all the firms in the final sample had already implemented Web technologies in SCM. Almost half the firms in the sample had deployed Web technology less than two years before the survey was administered, and the others had deployed it much earlier.

The CIO or the senior IT executive was reached in most cases. More than half of the respondents held the most senior IS positions in their firms. About a fifth were from IS management or the equivalent. Interestingly, 12 percent of the respondents had titles allied to Web-related functions in the organizations. Overall, the respondent profile gives good confidence in the data obtained by the survey.

Response bias is always a concern in survey research, especially when the response rate is low. As indicated earlier, the response rate was comparable to similar studies. However, several steps were taken to assess response bias. Following Armstrong and Overton, the early respondents and late respondents were compared on a number of parameters [4]. The logic of this comparison is that late respondents tend to closely resemble nonrespondents [50]. Nonrespondent bias was checked by comparing early and late respondent firms on all the key research constructs in the model. The t-tests revealed no significant differences in the means of the research constructs between the two groups. Second, on the assumption that a significant correlation between item scores and survey response time would indicate response bias, all the correlations between the mean scores of the research constructs and response time were examined, and none were significant. Third, industry bias was also examined. Because there were more than 13 industry groups in the sample, with fewer than five firms in some of the industries (see Table 3), they were
regrouped into seven industry categories in order to perform chi-square tests.

The respondent and late-respondent groups were compared to see whether

<table>
<thead>
<tr>
<th>Industry</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing/engr.</td>
<td>32</td>
<td>18.2</td>
</tr>
<tr>
<td>Chemical</td>
<td>3</td>
<td>1.7</td>
</tr>
<tr>
<td>Finance/banking/insurance</td>
<td>26</td>
<td>14.8</td>
</tr>
<tr>
<td>Computer/IT</td>
<td>14</td>
<td>8.0</td>
</tr>
<tr>
<td>Medical/health care</td>
<td>5</td>
<td>2.8</td>
</tr>
<tr>
<td>Oil/gas/energy</td>
<td>6</td>
<td>3.4</td>
</tr>
<tr>
<td>Business services</td>
<td>9</td>
<td>5.1</td>
</tr>
<tr>
<td>Real estate/property</td>
<td>7</td>
<td>4.0</td>
</tr>
<tr>
<td>Publishing/Information/news</td>
<td>6</td>
<td>2.4</td>
</tr>
<tr>
<td>Transportation/logistics</td>
<td>12</td>
<td>6.8</td>
</tr>
<tr>
<td>Retailing/Wholesale/Trading</td>
<td>24</td>
<td>13.6</td>
</tr>
<tr>
<td>Hotel/hotel/Travel</td>
<td>6</td>
<td>3.4</td>
</tr>
<tr>
<td>Other</td>
<td>17</td>
<td>9.7</td>
</tr>
<tr>
<td>N/A</td>
<td>10</td>
<td>5.7</td>
</tr>
<tr>
<td>Total</td>
<td>176</td>
<td>100.0</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Annual revenue level</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1 million</td>
<td>1</td>
<td>0.6</td>
</tr>
<tr>
<td>1.1–5 million</td>
<td>4</td>
<td>2.3</td>
</tr>
<tr>
<td>5.1–10 million</td>
<td>13</td>
<td>7.4</td>
</tr>
<tr>
<td>10.1–50 million</td>
<td>39</td>
<td>22.3</td>
</tr>
<tr>
<td>&gt;50 million</td>
<td>56</td>
<td>31.8</td>
</tr>
<tr>
<td>N/A</td>
<td>1</td>
<td>0.6</td>
</tr>
<tr>
<td>Total</td>
<td>176</td>
<td>100.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time elapsed since Web technology deployment</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1 year</td>
<td>9</td>
<td>5.1</td>
</tr>
<tr>
<td>1 year</td>
<td>39</td>
<td>22.1</td>
</tr>
<tr>
<td>2 years</td>
<td>41</td>
<td>23.3</td>
</tr>
<tr>
<td>3 years</td>
<td>24</td>
<td>13.6</td>
</tr>
<tr>
<td>4 years</td>
<td>29</td>
<td>16.8</td>
</tr>
<tr>
<td>5 years</td>
<td>19</td>
<td>10.8</td>
</tr>
<tr>
<td>N/A</td>
<td>15</td>
<td>8.52</td>
</tr>
<tr>
<td>Total</td>
<td>176</td>
<td>100.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Title of respondent</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIO/CTO/vice president for IS/senior vice president for IS</td>
<td>63</td>
<td>35.80</td>
</tr>
<tr>
<td>Senior directors/director for IS</td>
<td>28</td>
<td>15.91</td>
</tr>
<tr>
<td>General manager/manager, vice president, or assistant director for IS</td>
<td>35</td>
<td>19.89</td>
</tr>
<tr>
<td>Vice president/director for e-Business</td>
<td>8</td>
<td>4.6</td>
</tr>
<tr>
<td>General manager/e-business manager</td>
<td>14</td>
<td>7.95</td>
</tr>
<tr>
<td>Project manager/project leader for e-business</td>
<td>5</td>
<td>2.84</td>
</tr>
<tr>
<td>IS project manager, executive manager/other</td>
<td>6</td>
<td>3.4</td>
</tr>
<tr>
<td>N/A</td>
<td>19</td>
<td>10.80</td>
</tr>
<tr>
<td>Total</td>
<td>176</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Table 3. Demographics of Responding Firms.
they differed across the industry representations, and no significant differences were found. Similarly, the distributions of the revenue levels of these two groups were compared, and no significant differences were detected. Fourth, to test for sample bias, the respondent firms that had returned usable questionnaires indicating that they had deployed Web-based systems in the supply chain \( (n = 176) \) were compared with those that had indicated otherwise \( (n = 73) \). The chi-square test on the revenue levels suggests a possible bias \( \chi^2 = 39.75; p < 0.1 \), implying that the respondent firms that had deployed Web-based supply-chain systems were large firms with fairly high levels of revenue. Therefore, the results need to be interpreted with caution inasmuch as they may be applicable only to larger firms.

**Analytical Techniques**

The research model was tested with structural equation modeling (SEM) using the partial least squares (PLS) approach [62, 102, 103]. PLS is a second-generation modeling technique that simultaneously assesses the quality of measurement of research constructs (i.e., measurement model) and the inter-relationships between the constructs (i.e., structural model). Unlike other SEM techniques, such as LISREL, that use maximum likelihood estimation to gauge the fit between a theoretical model and the covariance matrix of the observed data, PLS assesses the relationships between the research constructs, and between the constructs and their measurement items, so that the error variance is reduced. Whereas LISREL tests a model and produces fit measures explaining how well the observed data fits the theoretical model, PLS seeks to explain the relationships within a model [32]. PLS assesses the predictive relationships in the model and tests how well one part of the model predicts values in other parts. Therefore, PLS is better for analyses of exploratory models with no or little rigorous theoretical grounding but where explaining the construct interrelationships is desired [31]. Moreover, PLS works under conditions of nonnormality and can handle smaller samples. All of these qualities have earned PLS wide acceptance by IS scholars [3, 18, 85].

The present research assessed a set of interrelationships among key factors, assimilation/diffusion of Web technologies, and the benefits realized from Web systems. The primary focus was on the strength of the relationships in the model. The sample comprises 176 cases, which is considered adequate for PLS analysis. Therefore, PLS was the appropriate analytical technique for the study.

**Measurement Model**

The data analysis began by assessing the mensurational properties of the research constructs. Testing a measurement model involves examining the internal consistency, convergent validity, and discriminant validity of the constructs. Internal consistency was examined using composite reliability. The traditional reliability measure of Cronbach’s \( \alpha \) assumes equal weight for
the items measuring the construct and is influenced by the number of items in the construct. In PLS, however, composite reliability relies on actual loadings to compute the factor scores and is therefore a better indicator of internal consistency. As shown in Table 4, the composite reliability values for the constructs in the model were all above the suggested threshold of 0.7 and thus supported the reliability of the measures.

Convergent validity refers to the extent to which two or more items measuring the same variable agree. Two tests were used to assess convergent validity. The first was item reliability, which examines the factor loading of each item on the variable. Falk and Miller recommend a loading level of 0.55 to assess item reliability [28]. As can be seen in Table 2, all the items had a loading above the suggested threshold, thus providing support for item reliability. The second test for checking convergent validity is average variance extracted (AVE). The AVE for a construct reflects the ratio of the construct’s variance to the total amount of variance among the items. Table 4 shows that the AVE values for all the constructs were above the limit of 0.50 advised by Fornell and Larcker [33]. Hence, the variables in the measurement model demonstrated adequate internal consistency and convergent validity.

Discriminant validity refers to the extent to which a given construct differs from other constructs. Two tests were used to evaluate discriminant validity at both the item and construct levels. According to Barclay, Higgins, and Thompson, no item should load more highly on another construct than it does on the one it is intended to measure [5]. Table 2 presents the loadings for the hypothesized relationships between the construct and its measures. The table indicates adequate discriminant validity at the indicator level. At the construct level, discriminant validity is adequate when the variance between a construct and any other construct in the model is less than the variance of the construct with its measures [31]. The variance shared by any two constructs is obtained by squaring the correlation between them. The variance between a construct and its measures corresponds to the AVE. Discriminant validity was evaluated by comparing the square root of the AVE for a given construct with the correlations between the construct and all other constructs. Table 5 presents the construct intercorrelations, and Table 4 presents the values of AVE.

<table>
<thead>
<tr>
<th>Construct</th>
<th>Composite reliability</th>
<th>Average variance extracted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier interdependence</td>
<td>0.70</td>
<td>0.77</td>
</tr>
<tr>
<td>Competitive intensity</td>
<td>0.85</td>
<td>0.92</td>
</tr>
<tr>
<td>IT activity intensity</td>
<td>0.73</td>
<td>0.83</td>
</tr>
<tr>
<td>Managerial IT knowledge</td>
<td>0.80</td>
<td>0.88</td>
</tr>
<tr>
<td>Centralization of IT unit structure</td>
<td>0.71</td>
<td>0.77</td>
</tr>
<tr>
<td>Formalization of IT unit structure</td>
<td>0.73</td>
<td>0.76</td>
</tr>
<tr>
<td>Assimilation</td>
<td>0.82</td>
<td>0.89</td>
</tr>
<tr>
<td>Diffusion</td>
<td>0.92</td>
<td>0.95</td>
</tr>
<tr>
<td>Benefits realized from Web Technologies in SCM</td>
<td>0.85</td>
<td>0.91</td>
</tr>
</tbody>
</table>

Table 4. Reliability and Average Variance Extracted of Constructs.
<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
<th>Realized benefits</th>
<th>Assimilation</th>
<th>Diffusion</th>
<th>Centralization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Realized benefits</td>
<td>2.99</td>
<td>1.34</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assimilation</td>
<td>3.11</td>
<td>1.74</td>
<td>0.74</td>
<td>1.00</td>
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<td></td>
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<tr>
<td>Diffusion</td>
<td>2.94</td>
<td>1.61</td>
<td>0.73</td>
<td>0.73</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Centralization</td>
<td>5.24</td>
<td>0.97</td>
<td>-0.31</td>
<td>-0.31</td>
<td>-0.24</td>
<td>1.00</td>
</tr>
<tr>
<td>Formalization</td>
<td>4.37</td>
<td>1.25</td>
<td>0.22</td>
<td>0.39</td>
<td>0.23</td>
<td>-0.11</td>
</tr>
<tr>
<td>Supplier interdependence</td>
<td>4.10</td>
<td>1.09</td>
<td>0.36</td>
<td>0.23</td>
<td>0.20</td>
<td>-0.02</td>
</tr>
<tr>
<td>Competitive intensity</td>
<td>4.85</td>
<td>1.32</td>
<td>0.55</td>
<td>0.18</td>
<td>0.20</td>
<td>-0.15</td>
</tr>
<tr>
<td>IT activity intensity</td>
<td>4.18</td>
<td>1.28</td>
<td>0.45</td>
<td>0.64</td>
<td>0.46</td>
<td>-0.30</td>
</tr>
<tr>
<td>Managerial IT knowledge</td>
<td>4.88</td>
<td>1.36</td>
<td>0.19</td>
<td>0.26</td>
<td>0.17</td>
<td>-0.12</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Formalization</th>
<th>Supplier interdependence</th>
<th>Competitive intensity</th>
<th>IT activity intensity</th>
<th>Managerial IT knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Realized benefits</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Assimilation</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Diffusion</td>
<td></td>
<td></td>
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<tr>
<td>Centralization</td>
<td></td>
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</tr>
<tr>
<td>Formalization</td>
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<td>1.00</td>
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<td></td>
<td></td>
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<tr>
<td>Supplier interdependence</td>
<td>0.29</td>
<td>0.10</td>
<td>1.00</td>
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</tr>
<tr>
<td>Competitive intensity</td>
<td>0.26</td>
<td>0.09</td>
<td>0.16</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>IT activity intensity</td>
<td>0.24</td>
<td>0.11</td>
<td>0.08</td>
<td>0.30</td>
<td>1.00</td>
</tr>
<tr>
<td>Managerial IT knowledge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Descriptives and Intercorrelations.
In every case, the shared variance between two variables was less than the AVEs, satisfying the requirements of discriminant validity.

**Structural Model**

Partial least squares is a nonparametric estimation procedure, and it does not offer significance tests based on statistical distributions. The size and significance of the paths in the model were examined by using bootstrapping to estimate parameters, standard errors, and t-values [72]. A total of 250 random samples of observations was generated from the original data set by sampling through replacement, where each sample size was similar to the number of cases in the original data set. The resulting PLS structural model, along with the path coefficients and their significance values, are shown in Figure 2 and Table 6.

All the hypothesized paths, with the exception of the one linking competitive intensity and the diffusion construct, were found to be significant ($p < 0.01$). The model accounted for 24.3 percent of the variance in internal assimila-
lation, 58.1 percent of the variance in external diffusion, and 62.1 percent of the variance in the realized benefits from deploying Web technologies in SCM. These figures imply that the study’s constructs and the predicted paths accounted for a significant portion of the variance in the dependent variables.

The analysis was rerun after the PLS model was revised by removing the path between internal assimilation and external diffusion. This reduced the multiple correlation square value for external diffusion from 0.581 in the original model to 0.291 in the revised model. Without the linkage between assimilation and diffusion, the model accounted for 29.1 percent of the variance in external diffusion. However, with assimilation added as a predictor variable, the variance explained in diffusion increased to 58.1 percent. This offered additional support for H7, which proposed a positive association between internal assimilation and external diffusion.

All of the hypotheses except H2 were supported by the study. Interdependence of suppliers and IT activity intensity were found to influence external diffusion positively, whereas managerial IT knowledge and formalization of the IT unit structure were positively associated with assimilation of Web technologies in SCM. As expected, centralized IT unit structure was negatively associated with assimilation. The impact of Web technologies in SCM was found to have strong positive associations with both the internal assimilation construct and the external diffusion construct. This implies that Web technologies are likely to have stronger positive impacts on SCM if the technology is both internally assimilated and externally diffused in the SCM function.

Discussion and Conclusions

More and more firms are adopting Web technologies and systems in their supply-chain operations, but there has been little empirical research on the assimilation and diffusion of these systems, their key drivers, and the performance impacts. Drawing upon theoretical perspectives from organizational theory, IS research, and SCM research, the study described in this paper investigated the key environmental and organizational factors that affect the
assimilation and diffusion of Web technologies in SCM and the resultant performance impacts.
Among environmental factors, IT activity intensity and supplier interdependence were found to have a positive relationship on the diffusion of Web systems in SCM. The greater the mutual dependence between a firm and its suppliers, the greater the likelihood that the firm will diffuse Web technologies among its supplier networks. This significant result for supplier interdependence has another interesting dimension related to the argument that Web technologies, unlike EDI systems, lower the switching costs of B2B relationships with suppliers. If the enhancement of Web technology diffusion when there is greater mutual dependence can be expected to lower switching costs in the long term, this will aid in the transformation of static supply chains into dynamic supply chains, as characterized by Kumar and Christiaanse [57]. They argue that dynamism in the choice of partners in the supply chain is a critical requirement for supply-chain transformation.

The findings regarding the impact of IT activity intensity on the diffusion process are interesting. When key supply-chain players begin to use Web technologies, other firms respond to the peer pressure to adopt the technologies, especially if their SCM operations are tied closely to those of outside parties. Thus, it is not an internal need for Web connectivity, but the need to establish external SCM connectivity and supplier interdependence, that apparently drives the diffusion of Web technologies. No support was found for the view that competitive intensity per se influences Web technology diffusion. In all probability, the IT activities of competitors and the extent of IT use in the industry have a stronger impact than the competitive pressure faced by firms. These results are similar to those of Iskander, Kurokawa, and LeBlanc, who reported an insignificant relationship between competitive intensity and the extent of EDI adoption and integration [47].

Of the organizational variables, higher levels of managerial IT knowledge were found to have a positive effect on the assimilation process. This complements the results obtained by Armstrong and Sambamurthy and by Chatterjee, Grewal, and Sambamurthy, who found that collective IT knowledge in the organization is a key predictor of technology assimilation [3, 17]. Organizations with an enlightened understanding of the strategic potential of Web technology for improving SCM assimilate Web technology more easily and pervasively than firms whose senior business and IT executives lack such knowledge and understanding.

The study also found that IT unit structures had a significant effect on the assimilation of Web technologies in SCM. Web-based supply-chain projects need active participation from operations, logistics, warehousing, and other functional managers apart from IT executives. Only a collective effort can enhance the effective usage of Web technologies in SCM. The use of formal mechanisms, such as guidelines and rules, and the assignment of formal responsibilities to task forces or interdisciplinary teams for executing Web-based SCM projects, augment Web-technology assimilation.

It is also important to consider the positive relationship between the internal assimilation and external diffusion of Web-based SCM applications. Until now, research has largely ignored this critical linkage, possibly because of an
assumption that the two constructs are separate and distinct. The present findings, however, suggest that they are closely linked. Firms that have e-enabled their internal supply-chain operations, such as manufacturing logistics, inventory planning, and warehouse management, are more likely to succeed in diffusing these technologies into the interorganizational supply chain. This empirical finding lends support to the idea that before moving forward on ambitious plans for the use of Web technologies for B2B transactions and coordination with supply-chain partners, organizations should first ensure that their internal processes and "back-end" logistics systems are adequately Internet enabled. Much like the lesson learned by many virtual e-retailers during days of the dot-com boom, it is imperative for organizations to pay as much attention to the assimilation of Web technologies for internal logistics coordination as to the interorganizational diffusion of Web-based systems with their supply-chain partners.

From a research perspective, the critical link between the internal assimilation and external diffusion of new technology applications is very important. Past MIS research on the diffusion of EDI and IOS may have assumed that the internal assimilation of new technologies builds capabilities that improve a firm’s ability to diffuse IOS in the extended enterprise. However, the reverse influence of the external diffusion of IS technologies/capabilities on longitudinal, internal assimilation within organizations could possibly be a motivation for the study of several recently observed phenomena, such as informational cascades, information system waves, and mimetic imitation in new technology acquisition [53, 54, 97, 99].

Researchers and practitioners are focusing more attention on the performance impact of Web technology and systems. The study found significant positive associations between both assimilation and diffusion of Web technologies and the benefits from Web technologies in SCM. This shows that greater usage of Web systems in SCM is likely to improve performance in the areas of customer service, cost reduction, inventory management, cycle-time reduction, supplier-relationship management, and overall competitive advantage. These results are consistent with those of Frohlich and of Frohlich and Westbrook, who found that stronger e-integration between a firm and its suppliers influenced performance [34, 35]. A firm seeking to derive greater benefit from Web systems needs to concentrate as much on internally assimilating these systems into its operations as on externally diffusing them across its supplier networks. Thus, the present study directly complements the studies that emphasize system usage as a significant influence on the value generated from IT [23, 65].

Contributions to Research and Practice

The study summarized in this paper has made some significant contributions:

1. It adds to the emerging body of research on Web technology assimilation and diffusion in organizations by throwing light on the performance impacts of Web technology diffusion and on the key factors affecting Web technology assimilation and diffusion.
2. It provides insights into real-world Web-SCM efforts, an area where there have been relatively few empirical studies based on field data because of the dominance of analytical modeling and practitioner case study as the main approaches to the study of SCM. The organizational factors that need focus when a firm is embarking on e-business initiatives are identified. The importance of improving and sustaining higher levels of managerial IT knowledge and designing organic IT unit structures is highlighted. Formalization generally inhibits innovation in organizations, but formalizing IT activities and processes could greatly facilitate the organizational assimilation of Web technologies.

3. It takes a holistic approach, in contrast to earlier studies, which focused either on assimilation or on diffusion but not on both. A holistic approach that examines the two concepts and their interrelationships facilitates better understanding of Web technology assimilation and diffusion in SCM. The results indicate that external diffusion is contingent upon internal assimilation of Web systems, and both constructs collectively contribute to the benefits realized from Web applications.

4. It provides strong evidence that the returns from Web applications in SCM will be positive. Firms can maximize the benefits of Web technology by assimilating these technologies with their internal processes and by externally diffusing them in their supply chains.

5. It is grounded on existing theories of innovation diffusion and the extended enterprise. By building on earlier research, the study shows how these theories can be used to explain the assimilation and diffusion of Web-based SCM.

Given the critical role of Web technologies in the implementation of SCM, it is important to understand the implications of the study’s findings for practice.

1. An understanding of the key factors affecting SCM assimilation and diffusion will put practitioners in a better position to design appropriate strategies to deal with SCM deployment and, consequently, to enhance its benefits.

2. The IT unit plays a critical role in the implementation of SCM. Given that structural attributes, such as centralization and formalization of the IT unit and managerial IT knowledge, significantly affect assimilation, it is imperative for top management to think carefully about the role of IT managers in SCM initiatives. Before beginning a major SCM program, managers may want to think about implementing managerial mechanisms that will improve managerial IT knowledge and ensure decentralization and formalization of IT management and decision making.

3. The same lessons apply to IT managers faced with supporting organizational SCM programs and can guide them in adopting appropriate guidelines and managerial postures that will ensure successful Web-related SCM initiatives.
4. Organizations may want to adopt a two-pronged “internal assimilation/external diffusion” strategy in dealing with the IT challenges posed by the use of Web technologies for SCM, because both of these factors will yield significant performance impacts. Even if they are cognizant of the interrelationship between assimilation and diffusion, managers may want to note that internal logistics assimilation of Web technologies for SCM yields benefits.

5. The dynamics of implementing Web-based systems in SCM will be more challenging for managers operating in environments characterized by high levels of supplier interdependence and IT activity intensity. Careful consideration must be given to planning and implementing Web-based SCM systems in such environments.

6. The study provides a basis for managerial thinking about the types of performance benefits that can be expected from investments in Web technology applications for SCM.

7. The study’s empirical evidence on performance benefits should assure top management that investments in Web-based technologies for SCM are worthwhile.

Limitations and Future Research

The study has some important limitations. To begin, its results are based on the perceptions of senior IT executives rather than SCM managers, because all of the respondents were senior IT executives. However, given that the research constructs examined levels of IT knowledge, IT unit structure, and IT usage, senior IT executives were appropriate respondents. Future research can examine the perceptions of top managers and SCM managers with regard to Web-based SCM assimilation and diffusion.

Another important limitation pertains to the common method bias. When data on research variables are collected from the same source at one time, the relationships between variables may be contaminated by biases in the source that can lead to inflation in observed relationships. Several procedural and statistical steps were taken to address the problem of method bias because it is so important a concern. The variables were not placed in any particular order in the survey administered to the respondents. Some dependent variables were placed ahead of independent variables to diminish the cognitive complexity of the judgments made by the respondents when answering the questions. Harman’s single-factor test (see Podsakoff and Organ [77]; Harman [43]) was used by performing factor analysis to examine common-method bias. This test holds as a fundamental principle that if there is a substantial amount of common-method variance in the data, either a single factor will emerge from the data when all the dependent and independent variables are entered together, or a general factor that accounts for most of the variance will result. The factor analysis indicated the existence of nine factors that were consistent with the research model.

Another limitation is the use of a single respondent from each target firm, without collecting and cross-validating responses from other informants in
the same firm. The use of single respondents is questionable, because relying on only one informant to make complex social judgments about organizational characteristics increases random measurement error. However, the cost of using multiple informants and the possibility of lower response rates were deterrents against the use of multiple respondents. The survey was targeted to senior IT executives in an attempt to minimize the common method variance. Senior IT executives are more objective and knowledgeable about the operations and strategies of their firms, and thus were in a position to answer questions pertaining to organizational and environmental characteristics. Future research can mitigate the problem of common method bias by collecting data from more than one respondent per firm and comparing the perceptions of different stakeholders in SCM assimilation and diffusion.

Because the concepts used in the study relied on subjective measures, the benefits realized from the deployment of Web technologies were evaluated from subjective indicators rather than objective, tangible measures. Thus, the responses about the benefits of e-business technologies reflect the perceptions of the responding executives rather than actual or quantified benefits. Future researchers could incorporate objective measures, especially for the impact of Web technology usage for SCM.

The study examined only a few of the environmental and organizational variables that impact Web assimilation and diffusion. Several other factors, such as the supply-chain structure, complexity of processes, IT infrastructure, and the nature of the Web systems, could also influence Web assimilation and diffusion. This is another area for future research.

Finally, the study used the adopters of Web systems as the unit of analysis. It captured the measures and the relationships as viewed by the adopter/initiator firms. A good extension of the study would be to have suppliers or buyer-supplier dyads as the unit of analysis.

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