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Information Systems as Integrative Infrastructures: Information Integration and the Broader Context of Integrative and Coordinative Devices

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Abstract
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Keywords: Coordination, Information Systems, Integration, Supply Chain Management

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– INFORMATION INTEGRATION AND THE BROADER CONTEXT OF INTEGRATIVE AND COORDINATIVE DEVICES

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Information systems as integrative infrastructures – *Information integration and the broader context of integrative and coordinative devices*

Sanna Laukkanen*

ABSTRACT

In order to effectively utilize information systems in the integration and coordination of activities, the different aspects of information integration and the role of information systems in the broader context of integration and coordination need to be understood. To address this need, a conceptual framework for the assessment of information systems as an integrative infrastructure is proposed. In the framework, information integration is divided into three components of connectivity, data integration, and process integration. In addition, five categories of integrative and coordinative devices are suggested to facilitate the assessment of the integrative role of information systems in a broader context. With the help of the elements captured into the framework, a more comprehensive understanding of the integrative functions of information system infrastructures can be achieved, and complementarity between information systems and the different integrative and coordinative devices facilitated. Empirical examples from five supply chain relationships are provided to illustrate the framework.

Keywords: Coordination, Information systems, Integration, Supply chain management

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Introduction

The purpose of integration is to link the interrelated elements of an organization together so that the problems related to, for example, achieving unity of effort between interrelated but highly differentiated organizational subsystems (Lawrence & Lorsch, 1967a), unconnected "functional silos" (Hammer & Champy, 1993) or "islands of automation" (Hale et al., 1989) can be overcome. This linking is achieved by providing the organization with an integrative infrastructure which enables improved coordination of activities and hence, makes it possible for the organization to operate more effectively and efficiently.

In the last two decades, integration of organizations has attracted a lot of attention under the themes of business process reengineering (BPR) and enterprise resource planning (ERP). BPR focuses on the radical redesign and restructuring of organizations around horizontal processes that overcome the boundaries of departments and functional areas so that the information flows and links between activities are improved (see e.g. Grover & Malhotra, 1997; Hammer, 1990). ERP, in turn, can be considered as "a development objective of mapping all processes and data of an enterprise into a comprehensive integrative structure" (Klaus et al., 2000). While information technologies are often considered an important ingredient in facilitating BPR (Attaran, 2004; Broadbent et al., 1999; Hammer, 1990; Venkatraman, 1994), the discussion on ERP has essentially concentrated on information systems called ERP systems – configurable enterprise-wide information system packages that integrate information and information-based processes within and across functional areas in an organization (Kumar & Van Hillegersberg, 2000).

Both BPR and ERP, focusing initially on overcoming the boundaries within organizations, have gradually extended to cover also the inter-organizational aspect of integration. In fact, inter-organizational integration can be seen as a logical extension to integration within organizations as the latter has been identified as an essential prerequisite for effectively coordinating activities between organizations (Hart & Estrin, 1991; Narasimhan & Kim, 2001; Stevens, 1989; Truman, 2000). Regarding integration between organizations, an extensive discussion in academia as well as in industry has revolved around the concepts of supply chain management (SCM) and inter-organizational information systems (IOS). While SCM focuses on the management and coordination of the buyer-supplier dyads, chains or networks more efficiently and effectively (see e.g. Cooper et al., 1997; Mentzer et al., 2001; Tan, 2001), IOSs – discussed as early as 1966 by Kaufman – are essentially integrative information system infrastructures for supporting and enhancing interaction across organizational boundaries (Barrett & Konsynski, 1982). Lately, these two research areas have become increasingly intertwined, with the heightening interest in SCM promoting the role of information systems in the integration and coordination of operations between organizations (see the literature review by Gunasekaran & Ngai, 2004).

The need for integration arises from the necessity of managing interdependencies between activities carried out within and between organizations. Examples of the types of interdependencies between activities include pooled interdependence, sequential or producer/consumer relationship type of interdependence, reciprocal interdependence, as well as task/subtask and simultaneity interdependence (Malone & Crowston, 1994; Thompson, 1967). The management of interdependencies between activities, then, is called coordination (Galbraith, 1973; Malone & Crowston, 1994; March & Simon, 1958). While a number of disciplines such as organization theory, operations research and economics have studied coordination, and the systems and solutions examined have varied accordingly (see Malone & Crowston, 1994), the essence of coordination remains always the same – bringing elements into a common action, movement, or condition and to get them to act together in a smooth concerted way (Merriam-Webster, 2006)[1]. Through coordination, the complementarity of interdependent activities and coherency of understanding between interdependent actors is achieved (Simatupang et al., 2002) and thus, the movement from local to higher-level optimization in a given system is facilitated. In an effort to improve coordination between interdependent elements, integration may be applied (Barki & Pinsonneault, 2003). That is, integrative infrastructures such as information systems coupling the interdependent elements together may be developed to achieve a concerted flow of activities. However, instead of merely being considered as the implementation of technological infrastructures, integration should also address the coupling of other elements comprising an organizational system to support the achievement of the organization's operational and strategic objectives (Waring & Wainwright, 2000).

[1] In this paper the word coordination is used to refer to both the effort of concerting activites and the state of concerted action.

This conceptual paper contributes to the prior research on information systems and the coordination of activities by proposing a framework for the assessment of information systems enabled integration of organizations. In the framework, the utilization of information systems to facilitate information integration – i.e. the coupling of interdependent activities through information flows – is assessed through three interlinked components of connectivity, data integration and process integration. In addition, five categories of integrative and coordinative devices are proposed in the framework to provide a broader context for the assessment of information systems as an integrative infrastructure. Together, the components and integrative and coordinative devices provide a conceptual lens to be utilized in the analysis of information systems enabled integration within and between organizations. Through the adoption of the proposed framework, isolated analyses focusing only on information systems or some of the components of information integration can be avoided, a more comprehensive understanding of information systems as enablers of integration achieved, and compatibility between information systems and the different integrative and coordinative devices facilitated. By embracing this multifaceted view where both the different aspects of information integration and the role of information systems in the broader context of integration and coordination are acknowledged, the paper aims to promote the efficiency and effectiveness of coordination efforts as a whole. Hence, the paper addresses the lack of integrative frameworks needed to improve overall performance of cooperation between multiple parties as identified in (Simatupang & Sridharan, 2005). Finally, deriving from the contingency theories (see e.g. Burns & Stalker, 1994 (orig 1961); Galbraith, 1973; Lawrence & Lorsch, 1967b) the framework assumes that no "one-size-fits-all" solution exists regarding the optimal degree or devices of integration, but the contextuality of integration efforts needs to be acknowledged.

The remainder of the paper is structured as follows. First, an overview of the prior research on information systems enabled integration of organizations is provided. We then proceed with a presentation of the framework for the assessment information systems enabled integration. Empirical examples are provided to illustrate the framework and its application as an analytical tool. The concluding chapter summarizes the paper along with discussing its implications on research and practice.

Information systems and the integration of organizations

In information systems research, integration is typically seen either to represent the extent to which different information systems are interconnected and can communicate with one another, or the extent to which business processes of independent organizations are standardized and tightly coupled through computers and telecommunication technologies (Barki & Pinsonneault, 2005). Through the integration of information systems and thereby, information, improved integration and coordination of operations within and between organizations, also referred to as enterprise integration (Alsene, 1999; Giachetti, 2004; Kosanke et al., 1999; Noori & Mavaddat, 1998), can be achieved. Along with being integrated with the help of information systems, the operations may also be redesigned (Davenport & Short, 1990; Hammer, 1990; Riggins & Mukhopadhyay, 1994; Swatman et al., 1994; Venkatraman, 1994) to gain more substantial benefits. A variety of both strategic and operational benefits have been reported to accrue from information integration, especially when accompanied with reengineering efforts and collaborative practices (see e.g. Clark & Stoddard, 1996; Crook & Kumar, 1998; Frohlich & Westbrook, 2001; Iacovou et al., 1995; Johnston & Vitale, 1988; Kulp et al., 2004; Lee et al., 1999; Mukhopadhyay & Kekre, 2002; Mukhopadhyay et al., 1995; Raghunathan & Yeh, 2001; Rai et al., 2006; Sriram et al., 2000).

From the evolutionary perspective, information systems enabled integration of organizations can be seen to have developed in successive stages focusing on computer system networks, application networks, process networks and finally, organization networks (Kosanke et al., 1999). The technologies proposed for information integration in turn have included solutions such as databases and database management systems (DBMS) (Fry & Sibley, 1976; Silberschatz et al., 1991), material requirements planning (MRP), manufacturing resource planning (MRP II) and computer integrated manufacturing (CIM) systems (Doll & Vonderembse, 1987; Noori & Mavaddat, 1998; Yusuf & Little, 1998), enterprise resource planning (ERP) systems, enterprise application integration (EAI) and middleware (Bernstein, 1996; Hasselbring, 2000; Irani et al., 2003; Lee et al., 2003; Markus, 2000; Sprott, 2000; Themistocleous et al., 2004), data warehousing (Huang et al., 2002; Markus, 2000; Subramanian et al., 1997), and inter-organizational information system technologies and ecommerce solutions such as

Electronic Data Interchange (EDI)[1] (Elgarah et al., 2005; Swatman et al., 1994) and electronic marketplaces (Bakos, 1991; Choudhury & Hartzel, 1998; Eng, 2004).

In the prior literature, a variety of characterizations describing information systems enabled integration of organizations have been presented. These include for example dimensions for the analysis of the extent of inter-organizational information systems usage (Lee & Lim, 2003; Truman, 2000; Williams et al., 1998), technical and architectural layers of integration (Giachetti, 2004; Hamilton, 1999; Hasselbring, 2000; Themistocleous et al., 2004), stages of inter-organizational information systems integration (Barrett & Konsynski, 1982; Malone et al., 1987; Premkumar, 2000; Swatman et al., 1994), typologies of the nature of inter-organizational information systems integration (Benjamin et al., 1990; Chatterjee & Ravichandran, 2004; Choudhury, 1997; Hong, 2002; Johnston & Vitale, 1988; Kumar & Van Dissel, 1996; Malone et al., 1987; Premkumar, 2000) and frameworks for information systems enabled integration of processes such as RosettaNet (Kirchmer, 2004). While the research on information systems and the integration of organizations is abounding, frameworks facilitating the assessment of the integrative role of information systems in relation to a broader context of integrative and coordinative devices are still needed. To address this gap, a conceptual framework acknowledging the different components of information integration and a set of integrative and coordinative devices identified from the prior literature is proposed in this paper. The remainder of the paper is dedicated on the presentation of the framework along with its illustration with empirical examples.

Illustrative examples and empirical data

To illustrate the proposed framework and to demonstrate its application as an analytical tool, empirical data from five supply chain relationships will be used. The characteristics of the two focal companies and their five suppliers are presented in Figure 1.

The data was gathered as a part of a research project conducted in Finland in 2005 and studying the use of information technologies and other mechanisms in the integration and coordination of a total of nine supply chain relationships. The case study approach was chosen to facilitate comprehensive exploration of the dynamics present in the

[1] In addition to referring to traditional VAN mediated EDI solutions, EDI as a concept refers also to, for example, Internet EDI and EDI solutions based on XML (e.g. RosettaNet) (see e.g. Elgarah et al., 2005).

organizations (Benbasat et al., 1987; Eisenhardt, 1989). As the means of data collection, semi-structured interviews, lasting two hours in average, were used. Regarding the five supply chain relationships employed for the purposes of this paper due to their providing the richest illustration of the phenomenon studied, a total of 13 company representatives participated in the 9 interviews conducted. The interviews consisted of a series of open ended questions and the questions were sent to the interviewees in advance in order to make it possible for them to prepare for the interviews by acquiring answers and by inviting other representatives to the interviews. The interviews were recorded to avoid the pitfall of memory lapses and the transcriptions written based on the recordings were sent to the interviewees to be checked for possible errors. The interview data was supplemented by additional information such as process charts and other relevant documentation acquired from the companies.

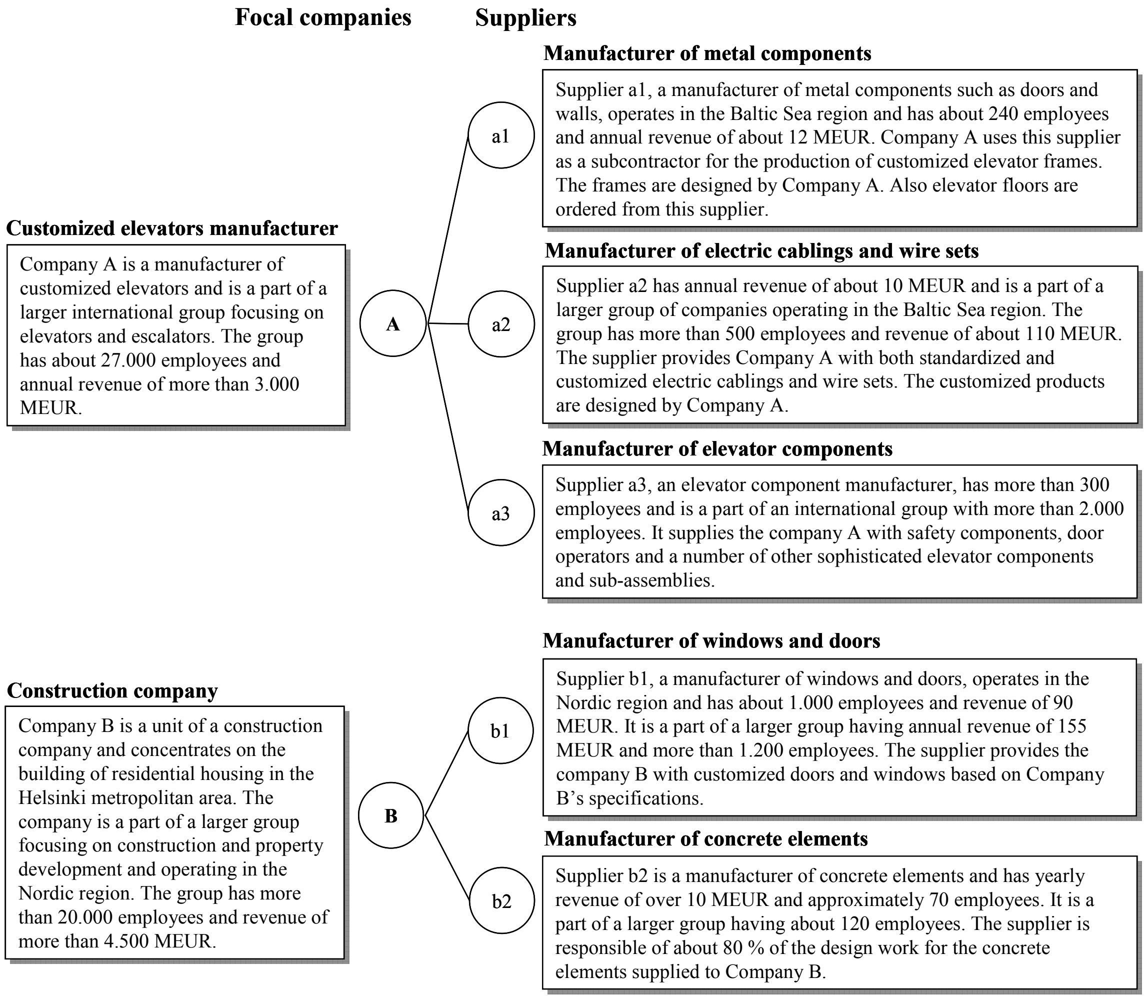

Figure 1 *Five supply chain relationships used for illustrative purposes*

To establish validity of the research, investigator and source triangulation were used (Lincoln & Guba, 1985). Multiple researchers participated in the interviews and checked the transcriptions written. Further, multiple respondents were typically present in the interviews and when possible, the representatives of both the focal company and the supplier were interviewed.

Components of information integration

In the framework proposed in this paper, the use of information systems as an integrative infrastructure is assessed through two dimensions: information integration and the broader context of integrative and coordinative devices. The first dimension, information integration, refers to the coupling of interdependent parties through information flows. To assess the different aspects of information integration, three components are proposed: connectivity, data integration and process integration (see Table I for an overview of the components). With the help of these components, the aspects of media, data, and processes of information exchange and utilization can be separately analyzed and thus, a more fine-grained picture of the current status, as well as of the potential, of the use of information systems for information integration achieved. Next, the proposed components are described in more detail. Along with descriptions, empirical examples from five buyer-supplier relationships are provided to illustrate each of the components.

Table I *Overview of the components of information integration*

COMPONENT	OVERVIEW AND ILLUSTRATION	
Connectivity	Communication media (and the related communication networks and protocols) used for connecting the parties.	*What types of communication technologies are used to connect the parties?*
Data integration	Standardization and formalization of data to create common language for communication and to reduce variability in the format and structure of the data shared. Definition of the structure and format of the messages to be used in data sharing. Centralized data storing to avoid duplication and inconsistency of data between the parties. Interoperability between applications so that the application used by one party can access and use data generated by the application used by the other party and the manual entry of data between the applications is avoided.	*Has the structure of data and messages been defined or standardized? Is there re-entry of data between applications? Does the receiver have to manipulate and reformulate the data before entering it into his own information systems?*
Process integration	Definition and standardization of information exchange practices: what data, who, when, how. Shared understanding between the parties to information integration on information requirements and on the utilization of information. Automatic sharing and processing of data between interdependent activities to provide embedded coordination of activities and thereby, facilitate their integration into processes.	*Has it been defined what information is exchanged, when and how? Is there a shared understanding on information requirements and the utilization of information? Is information exchange and processing automated to guide processes?*

Connectivity

Connectivity refers to data communication linkages connecting the parties to integration and addresses issues such as the media, networks and related protocols used in communication. In order to understand the context and potential of information systems use and to be able to assess whether information systems and other media support each other, the totality of the different media employed for information integration should be assessed. The connectivity between parties may be established by the means of, for example, telephone, fax, direct linkages between information systems (system-to-system linkages), web portals or hybrid solutions such as computer-to-fax communication. An essential difference between these different types of media is due to the differing degrees of human intervention required. In supply chains for example, manual and semi-automated phone, fax, and e-mail systems have been traditionally used in addition to face-to-face and paper-based communication to establish connectivity between organizations (see McLaren et al., 2002; Olhager & Selldin, 2004; Stefansson, 2002), while employing more automated solutions such as direct linkages between information systems would improve the efficiency of information exchange and free labor resources to focus on more value-added activities.

EXAMPLE 1: In Company A, connectivity with the suppliers a1, a2 and a3 is established through many different media. With Supplier a1, media such as letter and fax are extensively used along with direct linkages between information systems to exchange transaction information and hence, a lot of human intervention is associated with information integration. Meanwhile, with Supplier a2, connectivity is largely established through direct linkages between information systems. With Supplier a3, then, semi-automated computer-to-fax communication, direct linkages between information systems, as well as a web-portal are used to exchange transaction information. Email is used with all three suppliers for sharing of demand forecasts and performance metrics as well as for exception handling. Telephone, in turn, plays an important role in the communication of rush orders and in the solving of problem situations. Very central in information integration is also the web portal used by Company A to provide the suppliers with engineering documentation such as technical drawings. To summarize, at a moment, a variety of media are used by Company A to establish connectivity with its suppliers. While media such as email and telephone will remain important in the exchange of non-transactional information with the suppliers, the role of direct linkages will be increased to reduce the labor intensiveness of the exchange of transaction information especially with the suppliers a1 and a3.

EXAMPLE 2: In Company B, connectivity with the suppliers b1 and b2 is at the moment facilitated solely via manual media. For the ordering purposes, email is used with Supplier b1 and letter mail with Supplier b2, while bills are exchanged via letter mail and email respectively. With both of the suppliers, email is used to provide the suppliers with production plans, telephone for general communication and exception handling, and letter mail to share product specifications and drawings. In addition, fax is employed by the construction sites of Company B to provide connectivity with the suppliers when communicating about detailed delivery timetables. To reduce the amount of human intervention in providing *connectivity with the suppliers, inter-organizational information system solutions in the forms of direct linkages and web portal are planned for the exchange of technical specifications and drawings, and production plans respectively.*

Data integration

In data integration the focus shifts from media to the data structure and accessibility. The data communicated between the parties to information integration may be structurally formalized and standardized in order to create common language for communication and to reduce the variability in the format and structure of the data. Without agreed on and common language, increased ambiguity of meaning (see e.g. Bechky, 2003; Cramton, 2001) and processing costs are involved with information exchange, as the parties have to process and modify the shared data in order to be able to employ and act upon it (Argyres, 1999; Goodhue et al., 1992). Through the definition of the structure and format of the messages to be used in the exchange of specific information, also completeness of the information can be improved. Examples of the formalization and standardization of data are the exchange of data in the form of highly structured and standardized electronic messages using systems such as EDI (Damsgaard & Truex, 2000), and the use of shared data bases to enforce the unified representation of data and same definitions of data elements between the parties (Batini et al., 1986; Goodhue et al., 1992; Hamilton, 1999). In addition to formalizing and standardizing the format and structure of data, shared data bases facilitate data integration by promoting accessibility to data, and by helping avoid duplication and inconsistency of data between the parties to information integration (Davenport, 1998; Lee & Billington, 1992; Vosburt & Kumar, 2001). Solutions may also be developed to achieve interoperability between applications so that one application can access and use data generated by another and thus, the labor intensive and error-prone manual entry of data from one application or system to another can be avoided. Some examples of these are EAI solutions such as middleware and development of application programming interfaces (APIs) (Themistocleous et al., 2004).

EXAMPLE 3: Between Company A and Supplier a1, data integration has been hampered by the problems with establishing integration between the inter-organizational and internal information systems on the supplier-end. Hence, in addition to being transmitted via direct information system linkages, order data is also faxed to the supplier, and a lot of re-entering of data from one system to another is still involved especially on the supplier side, resulting in, for example, *delays in order confirmations. With Supplier a2, in turn, highly structured and standardized data is exchanged directly between information systems. However, also in this relationship, a lot of re-entry of data is needed on the supplier side due to the exchange of technical drawings via a web-portal. When an order arrives, the supplier manually enters the product design into its internal information systems based on the technical drawings submitted by Company A. To improve data integration, it has been suggested by the supplier that Company A would specify if a previously used technical drawing and thus, a product design already existing in the supplier's information system, has been used as a basis for orders. This requires that the technical drawings are accompanied by Company A with standardized identification and versioning data so that linking of new drawings to the previously used designs is facilitated. Finally, with Supplier a3, data integration in general is hampered by excessive re-entering of data on both sides. Some interoperability has been facilitated via a solution where packing lists are automatically downloaded from the supplier to the customer's information systems which then convert this data to an inbound delivery document and transfer it to a web portal to be accessed by the supplier in order to print package labels. Further, while order templates have been standardized, a common problem is erroneous specification data in the orders, as a result of which the supplier needs to return the orders to Company A to be corrected. In the future, data integration with this supplier will be improved by adopting linkages where highly structured data is transmitted directly between information systems.*

EXAMPLE 4: A common problem between Company B and Supplier b1 is incomplete specification data in orders, as a result of which the supplier needs to consult Company B to acquire the missing data. To improve the completeness and correctness of its orders, Company B is planning to adopt a product design database developed by the supplier and to use an interlinked application for ordering. The application forces the product specification data to be complete and will also be integrated with the internal information systems on both sides of the relationship, thus removing the manual re-entering of order information. Another development area is to provide the supplier continuous electronic access to the production plans of Company B, so that delays and interruptions in providing updated data, typical of repeated manual update submissions now taking place, can be avoided. In the relationship with Supplier b2, in turn, data integration has been promoted via definition of a set of standardized product designs to be used as a basis for orders by Company B. However, data integration is still hampered by excessive re-keying of data on both sides of the relationship. Hence, also with this supplier, integration and structuring of data flows between the parties with the *help of inter-organizational information systems and shared product design databases has been planned. In addition, the development of interoperability between the internal information systems of Company B has been identified as an important prerequisite for improved data integration with the suppliers.*

Process integration

In addition to the establishment of connectivity and data integration, the processes related to information exchange may be integrated. This involves the definition and standardization of information exchange practices by addressing issues such as what data, when, and how will be exchanged. The routines related to information exchange directly affect the information that is exchanged between parties through information systems (Patnayakuni et al., 2006), and without the establishment of standard practices and procedures, harmful ambiguity and unsystematic behavior easily start to hamper information exchange. Through the definition and standardization of information exchange practices, the predictability and compatibility of action between the parties to information integration, and hence, the integration of processes between them, can be improved. Also building a shared understanding between the sender and the receiver regarding the purpose of information exchange and on the utilization of the exchanged information is part of process integration. A mutual understanding on why and how information is to be exchanged and acted upon, helps to meet the information needs of the parties involved and to systematize and improve the exchange and utilization of information. Finally, the procedures of information exchange and processing may be embedded into information systems in order to facilitate the automatic integration of activities into processes and hence, to automate process coordination. Information systems may be used to, for example, automatically process data inputs and to share data between activities of the same or another process so that automatic coordination and systematicness at the process level will be achieved (see e.g. Davenport, 1998; Van Liere et al., 2004).

EXAMPLE 5: Between Company A and Supplier a1, information exchange is systematic due to the processes between these companies having become ingrained routines. However, in order to maintain the established knowledge on information exchange related to inter-organizational processes, and to easily pass this knowledge to new actors on both sides, formal descriptions of the routine patterns of action are needed. Further, one particular area requiring systematization in this *supplier relationship is the sharing of demand forecasts. Confusion and misunderstandings took place in Company A regarding the sharing of demand forecasts with the supplier, thus resulting in this activity being unsystematic. In the relationship with Supplier a2, in turn, problems in process integration occur due to the discrepancies between action and defined practices. While many practices have been mutually defined to guide information exchange related to order-delivery process, conformance to these definitions has been unsystematic, resulting in constant coordination problems and delayed deliveries. In addition there seems to be a lack of mutual understanding between the parties on the information needs of each other, especially in the areas of communicating about delivery problems and the sharing of demand forecasts, where development of systematic practices is now needed. Finally, with Supplier a3, process descriptions have been developed to guide information exchange. However, Company A needs to systematize and develop its demand forecasting processes in order for it to be feasible for the supplier to utilize the shared forecasts for the coordination of its own processes. To summarize, both the definition of information sharing practices and improved conformance with the defined practices are needed to improve process integration between Company A and its suppliers.*

EXAMPLE 6: Between Company B and Supplier b1, guidelines have been created to systematize the information exchange related to order-delivery process. However, there is a need for more comprehensive specifications and especially for a more thorough implementation of the specifications at the operative level. A specific area needing systematization is the communication related to the changes in the production plans by Company B. In order for the supplier to be able to effectively use the planning data shared by Company B as a basis for its own processes, the changes to the production plans need to be communicated to it systematically and on time. As a possible solution for this problem currently hampering the integration of processes between Supplier b1 and Company B, an implementation of an information system which automatically provides the supplier information on the customer's current production plans has been planned. Meanwhile, with Supplier b2, more detailed process specifications have been created to guide the information exchange. Problematic for achieving process integration, however, is the unsystematic compliance with these specifications as some information is not always exchanged like agreed or is not exchanged at all. For example, although standard product designs to be used as a basis for orders have been mutually defined, these designs are not systematically employed by Company B, resulting in additional work on the supplier-end and extra communication with Company B. Hence, with both supplier b1 and b2, *process integration is at the moment hampered by unsystematic action in information exchange.*

Conclusions

As can be concluded based on the empirical illustrations above, the components of connectivity, data integration and process integration, although separable, are interlinked and have implications on one another. Poor data integration for example has ramifications on process integration, as processes do not run smoothly due to erroneous or incomplete data, or errors and lags resulting from the manual re-entry of data (see e.g. Company B and Supplier b1). On the other hand, whether connectivity and data integration issues are in good order or not, problems in information integration occur if the processes of information exchange and utilization are not systematic (see e.g. Company A and Supplier a2). Hence, all three components should be addressed in order to facilitate information integration within and between organizations. Especially development initiatives striving towards the use of information systems as the enabler of information integration may easily become focused on connectivity and data integration issues while failing to address process integration issues (see Venkatraman, 1994) which then lead to inefficiencies in information integration. The need to acknowledge all three components is underlined by the observations made in the prior research where accompanying the implementation of information systems in order to improve data interchange with the reengineering of processes has been found important (see e.g. Clark & Hammond, 1997; Clark & Stoddard, 1996; Hammer, 1990; Venkatraman, 1994). It should also be acknowledged that the mere implementation of integrative infrastructures to facilitate connectivity, data and process integration is not enough, but the infrastructures have to be consistently applied in order for them to have a coordinative impact. Without consistent application of integrative infrastructures, unpredictability and ambiguities start to hamper the relationships between interdependent activities, and the coordinative power of the infrastructures is lost. Hence in order to achieve the benefits of information systems in information integration, the integrative infrastructures established in the areas of connectivity, data integration and process integration need to be systematically adhered to.

Broader context of integrative and coordinative devices

The second dimension of the proposed framework is based on the premise that in order to effectively and efficiently utilize information systems in the management of interdependencies between activities, information systems as enablers of integration should be assessed in relation to the broader context of integrative and coordinative devices. By adopting this broader view, organizations can ensure that the integrative information system infrastructures are aligned with the different integrative and coordinative devices employed by them, and that the different elements of the integrative infrastructure as a whole complement each other. As a result, the waste of resources due to deficiencies and incompatibilities in the overall integrative infrastructure is avoided. Therefore, to improve the efficiency and effectiveness of coordination efforts as a whole, an approach where the different integrative and coordinative devices along with information systems are designed and managed as a portfolio should be adopted by organizations. More importantly, the same approach should also be embraced by researchers to avoid isolated and unilateral analyses providing only a partial view of the overall integrative system, and to foster the building of a more thorough understanding of information systems in the integration and coordination of organizations.

A variety of integrative and coordinative devices can be identified from the prior literature. In order to provide an overview of this extensive field, the devices are divided here into five categories: incentive and norms, authority structures, lateral relations and boundary spanning structures, information and knowledge sharing, and specifications, standards, and controls. All the devices presented here can be seen to be applicable to integration and coordination both within and between organizations. Next, these five categories of devices will be described and their relationship with information systems enabled integration discussed.

Incentives and norms

Incentives and norms focus on the alignment of the interests and thereby, behavior of interdependent actors. Incentives include both financial and non-financial factors that induce an actor to choose a particular course of action, and are essentially a tool for affecting decision making and behavior of the actors by rewarding or penalizing a certain type of behavior and thereby, avoiding conflict of interest and improving coordination between actors. As a result of the aligned incentives the actors, while pursuing their own interests, simultaneously act according to the interests of the other actors instead of maximizing their own benefits at the expense of others. Examples of incentives are revenue sharing contracts, buy-back contracts, quantity flexibility contracts, pricing structures such as quantity or price discounts, cost and risk sharing, and tying of rewards and penalties to performance (Bagchi & Skjoett-Larsen, 2003; Cachon & Lariviere, 2005; Lambert & Cooper, 2000; Lee & Whang, 1999; Lee, 2000; Narayanan & Raman, 2004; Sahin & Robinson, 2002; Simatupang et al., 2002). As for norms, by aligning the values and beliefs between interdependent actors, a common cultural ground can be provided to the actors that guides them about the collective goals and appropriate means for attaining these goals (see e.g. Bagchi & Skjoett-Larsen, 2003; Grandori & Soda, 1995; Lambert & Cooper, 2000; Martinez & Jarillo, 1989; Mintzberg, 1979; Moch & Seashore, 1981; Ouchi, 1979; Ouchi, 1980).

Authority structures

Authority structures refer to the definition and allocation of responsibilities and decision rights between actors and to the specification of the lines of command and communication in order to facilitate the use of formal authority to manage interdependencies (see e.g. Galbraith, 1973; Martinez & Jarillo, 1989; Mintzberg, 1979). Consensus on decision rights and on the associated areas of responsibilities is an important prerequisite for, for example, smooth collaboration between supply chain members. Without prior agreement and consensus between the supply chain members on their legitimate spheres of operations and authority the relations between the members will be slowed down by persistent conflict over who does what (Simatupang & Sridharan, 2002). Further, through careful consideration and allocation of decision rights in a supply chain, the decision making right can be allocated to the actor that is in the best position to coordinate the interdependent operations (Lee, 2000). The same applies to activities within an organization where for example hierarchical authority structures (centralized, decentralized or a combination of these) or matrix type of dual authority structures can be used to allocate decision rights and to establish chains of command between the actors in order to facilitate coordination (see e.g. Galbraith, 1973; Harris & Raviv, 2002; Malone, 1997). In hierarchical structures each manager is allocated a responsibility of managing interdependencies in a certain area. If information needed to accomplish coordination of activities under his supervision is not possessed by a manager, the problem is referred upwards in the hierarchy (Galbraith, 1973).

Lateral relations and boundary spanning structures

Lateral relations and boundary spanning structures cut across the organizational boundaries and lines of formal authority and reporting relationships, thereby encouraging contacts and interaction between interdependent actors, and facilitating the solving of coordination issues between the actors through mutual problem solving and improved formal and informal communication. The devices in this category are as plenty as they are diverse, ranging from informal mutual adjustment, physical co-location, and temporary teams, task forces and boundary spanning assignments to permanent, formally established integrative departments, liaison roles, and teams and committees connecting actors within or between departments and organizations (see e.g. Adler, 1995; Bagchi & Skjoett-Larsen, 2003; Brown, 1999; Daft & Lengel, 1986; DeSanctis & Jackson, 1994; Edström & Galbraith, 1977; Galbraith, 1973; Gittell, 2002; Lawrence & Lorsch, 1967a; Lawrence & Lorsch, 1967c; Lawrence & Lorsch, 1967b; Lorsch & Lawrence, 1965; Martinez & Jarillo, 1989; Mintzberg, 1979; Pinto et al., 1993; Thompson, 1967; Van de Ven et al., 1976). Also matrix organization structures (temporary or permanent) are a device promoting lateral interaction (see e.g. Galbraith, 1973; McCann & Galbraith, 1981; Mintzberg, 1979). While facilitating the resolving of coordination issues collaboratively and reducing the need to resort to hierarchical decision making, devices in this category can be costly and time-consuming, and as a parallel structure to hierarchies, may sometimes lead to ambiguities about decision making rights and responsibilities.

Information and knowledge sharing

Information sharing is about the dissemination of information in order to facilitate choosing proper course of action, and to reduce information asymmetry and distortion between interdependent actors (Galbraith, 1973; Lee et al., 1997a; Sahin & Robinson, 2002; Simatupang et al., 2002). While the information exchanged can be of more operational nature such as prices and inventory levels or longer range planning type of information in order to facilitate the synchronization of future operations (see e.g. Lee & Whang, 2000), coordination through information sharing can also mean communication in different forums, the distribution of reports and announcements (Daft & Lengel, 1986; DeSanctis & Jackson, 1994), or the transmission of new information even as late as during the process of action in order to readjust operations on the fly (March & Simon, 1958; Thompson, 1967). Information sharing has been proposed to provide a number of benefits in, for example, the coordination of activities in supply chains (Bagchi & Skjoett-

Larsen, 2003; Lee et al., 1997b; Lee, 2000; Simatupang & Sridharan, 2002). To improve the information sharing capabilities of an organization, information technologies can be employed. However, information technologies should not to be treated as a silver bullet suitable for all situations but the media to be employed for information sharing and thereby, coordination, need to be adjusted to factors such as equivocality and uncertainty present in the situation (Daft & Lengel, 1986). Knowledge sharing, then, refers to improved coordination through collective learning between the interdependent parties (Bagchi & Skjoett-Larsen, 2003; Lee, 2000; Postrel, 2002; Simatupang et al., 2002). By continuously sharing their respective knowledge the parties can gain mutual and improved understanding and thereby, better coordinate their interrelated operations. One example of this is collaborative planning, forecasting and replenishment (CPFR) where supply chain members combine their intelligence in order to better plan and meet demand (Lee, 2000).

Specifications, standards, controls

Specifications refer to the definition of goals or targets such as budgets or margins to be met, the creation of schedules, and the establishment of plans for, for example, required activities and outputs (Adler, 1995; Galbraith, 1973; Ketokivi & Castaner, 2004; March & Simon, 1958; Martinez & Jarillo, 1989; Mintzberg, 1979; Pinto et al., 1993; Sicotte & Langley, 2000; Thompson, 1967; Van de Ven et al., 1976). With the help of specifications, interdependencies can be managed by planning for them in advance. Standardization, on the other hand, can be applied to reduce variation in work, skills or outputs and to establish a uniform response to or rules for a recurring situation and thereby, achieve coordination without a need to treat each situation as new (see e.g. Adler, 1995; Daft & Lengel, 1986; Galbraith, 1973; Martinez & Jarillo, 1989; Mintzberg, 1979; Pinto et al., 1993; Thompson, 1967). One example of standardization is the establishment of routine procedures to enable replication of processes and hence, facilitate coordinated action (Gittell, 2002). As compared to specifications, higher degree of stability is required for standards to be applicable as an integrative and coordinative device. Finally, while both specifications and standards coordinate action by regulating it in advance, controls are used for during-the-action (e.g. direct supervision) or "after-the-fact" monitoring of performance (Grandori & Soda, 1995; Lee, 2000; Martinez & Jarillo, 1989; Mintzberg, 1979; Ouchi & Maguire, 1975). In addition to allowing for improved coordination through the measurement of performance, controls enable the surveillance of conformance (of outputs, actions etc.) with the set specifications and standards and hence, are vital for them to retain their coordinative influence.

Aligning information system infrastructures with the devices

The five categories presented above provide a set of devices for the establishment of integrative infrastructures to be used for achieving and improving coordination. The applicability of a given integrative device to the situation at hand needs to be carefully considered in order for the device to facilitate effective and efficient coordination (see Adler, 1995; Daft & Lengel, 1986; Galbraith, 1973; Grandori, 1997; March & Simon, 1958; Van de Ven et al., 1976). Further, the devices employed should be carefully designed by organizations so that a comprehensive and solid portfolio of solutions where the different elements complement and match each other is achieved. Consequently, to avoid mismatches and conflicts in the overall integrative infrastructure, also the use of information systems for integrative purposes should be aligned with the set of integrative and coordinative devices employed. This requires that the linkages between the integration enabled by information systems and the different integrative and coordinative devices (see Table II) are carefully examined and addressed. To illustrate these linkages, a few examples are next provided.

First, in order to capture the benefits of information systems enabled information integration, the parties to integration have to be committed to it. This can be facilitated with incentives and norms. Through incentives, for example, the behavior detrimental to information integration can be made visible to the actor behaving adversely, and a motive provided for this actor to change his behavior. Incentives may also be required to facilitate the utilization of the shared information. An example of this is the adoption of risk and cost sharing practices to make the customer commit to its demand forecasts and to make it feasible for the supplier to use the shared forecast information for capacity planning and leveling.

> *In the relationship between Company A and Supplier a2 as well as Company B and Supplier b2, improved risk and cost sharing is needed to facilitate the use of the shared demand forecast information for capacity leveling and planning by the suppliers. At the moment, the companies A and B provide the suppliers with high level forecast information but do not commit to the forecasts, nor share the costs and risks of producing into inventory based on the forecasts. Hence, in case the suppliers try to level their capacity by producing into inventory well in advance*

based on the forecast information, they will become the sole carriers of the inventory costs as well as of the risk of changes in the required amounts and types of products. As a result of this incentive problem, the suppliers are not able to efficiently utilize the forecasts and are hard-pressed with delivering in time due to problems related to getting the required raw materials from their own suppliers as well as due to capacity overloading. For Supplier b1 in turn, common problem are the last minute delays in delivery timetables initiated by Company B and resulting in final products piling up in the supplier's warehouse. As no cost sharing practices are in place, the supplier has to bear the resulting inventory holding costs alone. In order for there to be an incentive for Company B to change its behavior and to inform the supplier about delays in time, cost sharing is needed between it and the supplier.

Table II *Integrative information system infrastructures and the linkages with the broader context of integrative and coordinative devices*

Incentives and norms	Incentives and norms can be applied to influence the parties' behavior and commitment related to information exchange and utilization, and to make information integration serve collective goals and interests. Incentives and norms can be embedded in and thus, their role as a device facilitated by information systems. (see e.g. Ba et al., 2001; Bakos & Brynjolfsson, 1993; Barua & Lee, 1997; Krumbholz & Maiden, 2001)
Authority structures	Authority structures can be used to allocate and define responsibilities and rights to utilize information as a basis of decision making and action. Information systems can be used to effectively and efficiently provide actors with information to be utilized as a basis when exercising their allocated authority. (see e.g. Davison, 2002; Gurbaxani & Whang, 1991; Hammer, 1990; Malone, 1997).
Lateral relations and boundary spanning structures	Interaction through lateral relations and boundary spanning structures facilitates the building of a shared understanding on the requirements of coordinated cooperation and makes it possible to develop information systems accordingly. Information systems can be used to facilitate lateral relations and boundary spanning structures. (see e.g. Dennis & Garfield, 2003; DeSanctis & Jackson, 1994; Kellogg et al., 2006; Levina & Vaast, 2005; Majchrzak et al., 2000)
Information and knowledge sharing	Information systems facilitate effective and efficient information and knowledge sharing between interdependent parties. (see e.g. Alavi & Leidner, 2001; Argyres, 1999; Bagchi & Skjoett-Larsen, 2003; Danese, 2006; Davenport, 1998; Goodman & Darr, 1998; Premkumar, 2000)
Specifications, standards and controls	Specifications, standards and controls can be built into information systems to provide automatic coordination of activities. Information integration can be supported via the employment of specifications, standards and controls to systematize the processes of information gathering and production. (see e.g. Argyres, 1999; Benders et al., 2006; Gumaer, 1996; Gurbaxani & Whang, 1991; Kohli & Kettinger, 2004; Yusuf & Little, 1998)

Second, authority structures help explicitly define who, and in what limits, makes decisions based on the exchanged information. Without a mutual agreement between the parties to information integration on the authority and limits in which the information can and should be used as a basis of decision making and action, information integration may be hampered by inefficiencies as well as ambiguities regarding responsibilities and rights to utilize the shared information. One example of authority allocation combined with information integration is the implementation of Vendor Managed Inventory (VMI) practice where the vendor is provided information on the customer's inventory status and allocated a responsibility to maintain the inventory in certain limits on the customer's behalf.

For Supplier b2, allocation of authority by Company B to produce into inventory within certain limits would facilitate the utilization of the received forecast information for the purposes of capacity planning and leveling. At the moment, a permit has to be applied by the supplier in order to start production which may be granted by Company B relatively close to the time of delivery. As a result the supplier sometimes has to start production without Company B's approval to secure availability of capacity as well as on time deliveries. For Supplier a2, in turn, the relocation of the inventories of standardized products to Company A's premises and the allocation of authority to maintain these inventories within agreed limits would reduce the coordination problems currently hampering the relationship. Supporting the sharing of demand forecast information, this allocation of authority would give the supplier better visibility to the actual demand and thus, help it plan its production and secure on time deliveries to Company A.

Third, sustained interaction between the parties to integration through lateral relations and boundary spanning structures facilitates a continuous enhancement of understanding between the parties on the requirements of coordinated cooperation and makes it possible to develop information integration and information systems accordingly. Without a shared understanding of the information needs of each of the parties, optimal support from information integration for the coordination of interrelated operations may remain unachieved.

In order to improve mutual understanding and to facilitate the solving of acute coordination problems, Supplier a2 hopes to establish weekly meetings with Company A. Regular meetings would support the formal information systems enabled information exchange taking place in this supply chain relationship by *providing continuous visibility to the other party's situation and by helping to identify possible coordination problems before they occur. What is more, as there seems to be a lack of mutual understanding on the requirements of information exchange and utilization between the parties, the regular meetings between the parties would provide a forum for mutually working on this issue. Supplier b2, in turn, considers to permanently locate one of its representatives in Company B's premises. This would help reduce current coordination problems by facilitating the participation of the supplier to the earlier phases of the order-delivery process and thus secure that the technical drawings and product specifications sent to the supplier are intact.*

Fourth, integration enabled by information systems is, by its very nature, closely associated with information and knowledge sharing. Through the careful development of integrative information system infrastructures, the use of information and knowledge sharing as a device can be made more effective and efficient. While the role of information systems in facilitating information and knowledge sharing has increased, also other media such as letter, telephone as well as face-to-face communication may be needed for information sharing and even more so for the purposes of knowledge sharing. Moreover, as information systems may not be able to serve all needs, the use of information systems as a facilitator of information and knowledge sharing should not be forced but stem from the requirements of the situation at hand. Important here is to achieve a solution where the needs for information and knowledge sharing between the parties to integration are efficiently and effectively met.

Instead of merely using information systems to blindly push information such as orders and demand forecasts to the suppliers, information sharing via personal communication is used by the Company A with its suppliers a1 and a3 to stay aware of the suppliers' capability to meet the demand and, for example, to secure that rush orders will be delivered in time.

Fifth, specifications and standardization can be used to support information integration. For example by standardizing the procedures related to gathering and production of information related to different operations, the harmful variance in the quality of information exchanged can be reduced. Without the quality of information being intact, the credibility and usefulness of information integration suffer regardless of the connectivity, data accessibility and structure issues being ok, and the information exchange per se being systematic. Violation of agreed upon standards and codes of conduct, in turn, hampers coordination despite the working information integration. Finally, the implementation of standards and specifications can be facilitated through their embedment into information systems. Information systems may also be employed to systematically monitor activities and hence, to facilitate the use of controls as an integrative and coordinative device.

> *To facilitate better utilization of the received demand forecast information, the suppliers a2, b1 and b2 hope for increased standardization of the products ordered by the companies A and B. While some of the products are already standardized, the variation in the outputs could still be heavily reduced in these supply chain relationships so that the high-level demand forecasts of the companies A and B could better be converted by the suppliers to the demanded volumes of specific product types. Further, to secure the supplier's capability to fulfill the orders, a rule of maximum order quotas has been defined between Company A and Supplier a2. However, as the quotas are often exceeded by Company A, problems in the supplier end occur. Hence, while information systems enabled information integration per se is in order, coordination problems result due to the violation of the agreed upon codes of conduct in ordering process.*

To put together the elements discussed above, in Figure 2 the three components of information integration and the five categories of integrative and coordinative devices are united into a framework for the assessment of information systems as an integrative infrastructure. Based on the framework, two propositions on the use of information systems as infrastructures to enable integration can be made. First, information integration consists of the components of connectivity, data integration, and process integration. Thus, *(1) in order to effectively and efficiently use information systems for information integration, i.e. the coupling of interdependent parties through information flows, the components of connectivity, data integration as well as process integration need to be addressed.* Second, information systems serve as a tool for supporting and enabling the use of a variety of integrative and coordinative devices. Therefore, *(2) the better the use of information systems as an integrative infrastructure is aligned with the set of integrative and coordinative devices employed, the more effective and efficient will the integrative infrastructure as a whole become.*

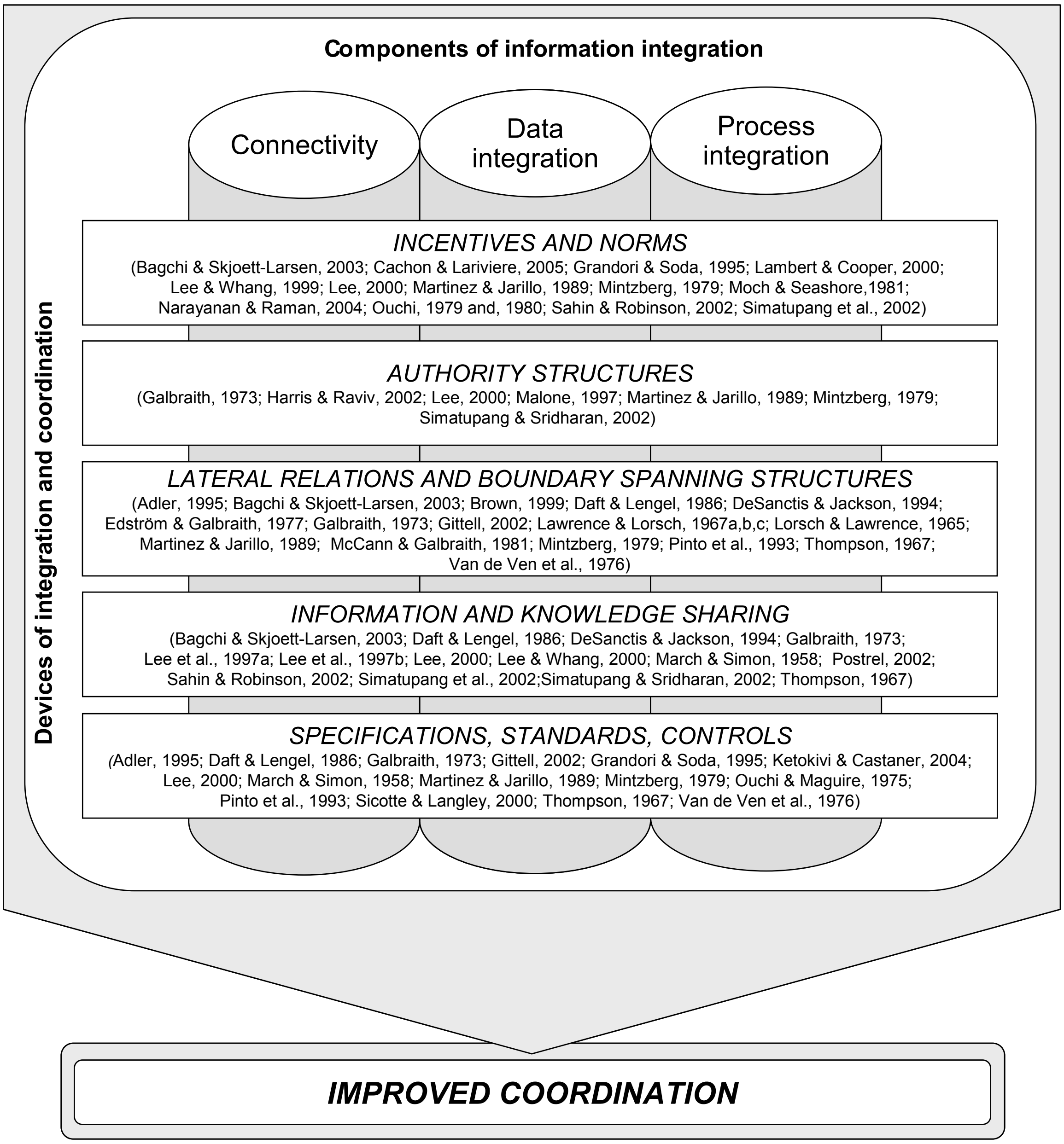

Figure 2 *Framework for the assessment of information systems as an integrative infrastructure*

In conclusion, it should be acknowledged that the development of integrative infrastructures – be they in the form of information systems, incentives or other – must be business driven, so that the resulting infrastructure as a whole effectively and efficiently meets the business needs of the parties involved. In other words, in addition to ensuring that the different elements in the portfolio of integrative and coordinative solutions do not conflict but complement each other, the development of the portfolio must conform to and originate from the organizational requirements.

Conclusions

For the purposes of this paper, integration was defined as the coupling of elements by providing an infrastructure that facilitates better coordination between these elements. To contribute to the extant literature on information systems and the coordination of activities, a framework consisting of three components of information integration and a broader context of integrative and coordinative devices was developed for the assessment of information systems as an enabler of integration. To illustrate the framework and its use as an analytical tool, empirical data from five supply chain relationships was employed.

The components proposed in the framework for the assessment of information integration address the issues of connectivity, data integration and process integration. While connectivity looks at the different types of media used for connecting the parties to integration, the focus of data integration is on the formalization and standardization of, as well as accessibility to, data. The process integration component, then, addresses issues such as the definition and standardization of the information exchange practices and shared understanding on the information requirements and utilization between the parties to information integration. What is more, the framework proposes that these three components are interrelated and hence, all of them should be taken into consideration when assessing the use of information systems for information integration within and between organizations. For example, as was seen in the empirical illustrations, although information systems may have been established to facilitate connectivity and data integration, information integration between supply chain partners may still be severely hampered by process integration problems such as unsystematic practices in information exchange as well as the lack of shared understanding on the information requirements and utilization. It was also demonstrated that the components, in addition to being applicable to the assessment of information integration already taking place, can as well be used for identifying areas of information integration where changes or more significant transformations via the implementation of information systems would be beneficial. By highlighting the separate but interrelated elements of media, data and processes, the components help build a more comprehensive understanding of the different aspects related to the employment of information systems as a tool for information integration.

To facilitate the assessment of the integrative role of information in relation to a broader context of integration and coordination, five categories of integrative and coordinative devices including incentives and norms, authority structures, lateral relations and boundary spanning structures, information and knowledge sharing, and specifications, standards and controls were introduced and discussed based on the prior literature. Examples of the linkages between information systems and each of the categories were provided and illustrated with the empirical data. Furthermore, it was proposed that in order to build effective and efficient total solutions for integration within and between organizations, the use of information systems as an integrative infrastructure needs to be aligned with the set of integrative and coordinative devices employed. This way, the compatibility between the different integrative and coordinative devices and integrative infrastructures enabled by information systems can be facilitated, and the efficiency and effectiveness of coordinative efforts as a whole improved.

The proposed framework has many implications on research as well as on practice. Firstly, information integration is a combination of three interlinked components. As a result, failure to address one component has implications to other components, resulting in the integrative information systems infrastructure not effectively supporting the coordination of interdependent activities through information. Secondly, to avoid isolated analyses of information systems in facilitating coordination, the use of information systems should be assessed in relation to the broader context of integrative and coordinative devices. More specifically, an approach where information systems and the different integrative and coordinative devices are managed and developed together should be adopted so that a more comprehensive understanding of the situation at hand and a solid overall infrastructure where the different elements complement each other will be achieved. Thirdly, the framework along with its empirical illustrations clearly implies that the establishment of integrative infrastructures in itself is not enough. In order for the integrative infrastructures to have a coordinative effect, the integrative infrastructures established need to be consistently employed. Without consistent application, the coordinative effect of integrative infrastructures deteriorates due to unpredictability and ambiguities characterizing the interdependent activities.

To conclude, while empirical illustrations were provided in this paper to demonstrate the proposed framework, assessment of the framework in the light of more extensive empirical data is needed to further evaluate its value for research as well as practice. To facilitate this, research operationalizing the different components of information integration and the broader context of integrative and coordinative devices, and the consecutive testing of the propositions presented in this paper along with the development of additional propositions is invited. Through the further developments of the portfolio approach to integration and coordination, a deeper understanding required for effective management of interdependencies within and between organizations will be achieved.

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