EXPLORING THE IMPACT OF ICT ON INTEGRATION IN SUPPLY CHAIN CONTROL: A RESEARCH MODEL

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ABSTRACT

The adoption of information and communications technology (ICT) is spreading rapidly in supply chain management. As companies seek to improve supply chain efficiency through increased integration, ICT can be considered as a key enabler for supply chain management by supporting information-sharing. A literature review within supply chain integration and the impact of ICT indicates that there are various integration dimensions and levels, and different effects and influencing factors. Even though there is a considerable amount of research within the field, the complexity of ICT impact on integration implies that previous studies cover only a limited number of dimensions and variables at a time. In this paper, we propose a research model that can support empirical in-depth studies seeking to explore how ICT influences integration in supply chain control. The model is developed from literature and incorporates areas of control, ICT, integration dimensions, ICT effects, influencing factors and supply chain integration.

Keywords: Information and communications technology, supply chain integration, control processes

INTRODUCTION

There is a rapid development in the use of information and communications technology (ICT) in logistics and supply chain management. ICT is today being applied in many organisations in a wide range and operations areas. It has provided new ways to store, process, distribute and exchange information both within companies and with customers and suppliers in the supply chain. ICT used to exchange information in the supply chain is often named interorganisational ICT or interorganisational information systems (IOIS).

In supply chain management, ICT has especially been recognised as an enabler for information-sharing which companies in the supply chain can use for eliminating the so called bullwhip-effect (Lee et al., 1997). Information-sharing is also a key component in many of the recent automatic replenishment programs (ARP) (Daugherty et al., 1999). Initiatives such as vendor managed inventory (VMI) and collaborative planning, forecasting and replenishment (CPFR) are based on an increased level of automation in both the flow of physical materials and goods and the flow of information between companies to improve the efficiency in the entire supply chain. In a operations management perspective, companies seek to further improve the efficiency in the supply chain by sharing information related to matching demand and supply such as short- and long-term production planning, demand forecasting and materials and capacity planning. Information that can be relevant to share between customers and suppliers typically includes point-of-sales data, forecasts and inventory levels.

There is a significant amount of research demonstrating a positive impact of ICT in the supply chain. As companies seek to improve the efficiency in the supply chain through increased integration, ICT can be considered as a key enabler for supply chain management through its ability to support information-sharing and shortening information processing time. Supply chain integration can however be expressed in a wide range of dimensions such as integration of processes, information, organisations and systems (Bowersox et al., 1999; Mouritsen, et al., 2003). Similarly, the impact of ICT can be demonstrated in terms of for instance changes in relationships, interorganisational changes and performance (Wilson and Vlosky, 1998). The many dimensions in which supply chain integration can be expressed and the wide variation of factors in which the impact of ICT can be defined in terms of integration indicates that previous research has been limited to studying a few dimensions and variables relationships at a time. The aspect of how to control and coordinate the activity between the companies in the supply chain, and how ICT affects the level of control integration in the supply chain is a poorly developed area.

We propose in this paper a research model for further research exploring the impact of ICT on integration in supply chain control. The model is primarily based on theory within supply chain integration and the impact of ICT. It also incorporates the supply chain control perspective, which defines the scope of application of the model. In contrast with previous research, this model does not intend to limited to a few pre-defined dimensions or variables for investigation but can be used to examine situations involving any type of integration dimension and influencing factor.

SUPPLY CHAIN CONTROL

This section gives an introduction to supply chain control with a focus on control processes and the different types of information typically shared in the supply chain for control purposes.

Control processes

In order to define how the control perspective is dealt with in this paper, the operations model developed by Alfnes (2005) is applied (Figure 1).

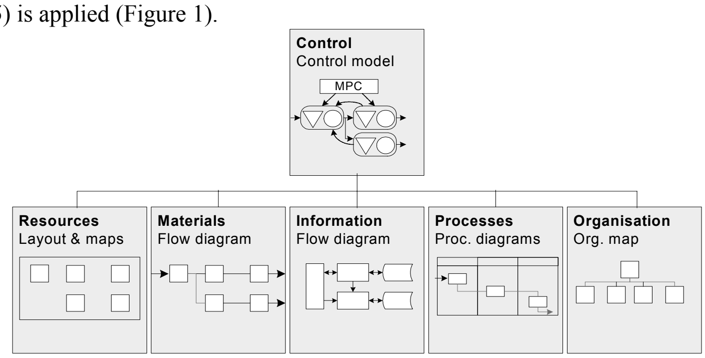

Figure 1 - The operations model-set (Alfnes, 2005)

The operations model-set is based on six views of enterprise operations and a set of description models that can be used for presenting each view. The model can be used for the design and analysis of operations. The views include resources, materials, information, processes, organisation and control. The first five views are aggregated into a control view that can be represented in a control model. Hence, the control perspective constitutes the top-layer of several operations areas in a company.

In order to identify typical control processes, two examples of control and planning frameworks are discussed. The first framework incorporates a set of modules of the manufacturing planning and control (MPC) system (Vollman et al., 2005), while the second framework involves various planning levels related to the materials and capacity perspectives (Mattsson and Jonsson, 2003). The two frameworks are hereafter referred to as the MPC framework and the planning framework.

The essential task of the MPC framework is to efficiently manage the flow of material, the utilisation of resources and to meet customer demand by providing information that supports management decisions. It is based on three phases; the front end, engine and back end. Measurement and control actions are considered as part of all the phases.

- The front end phase encompasses activities and systems for establishing the overall company direction for planning and control. It includes the modules of demand management, sales and operations planning (SOP), resource planning and master production scheduling (MPS). Demand management includes activities such as forecasting demand from customers, etc. Sales and operations planning balances the sales and marketing plans with available production resources, involving decisions about overall product volumes and mix. The MPS states the quantities and timing for specific products defined in the SOP and takes into consideration the capacity limitations, production costs and resource considerations. Resource planning constitutes the basis for matching manufacturing plans with capacity and defines the capacity needed to produce the current and future products.

- The engine phase covers the detailed material and capacity planning based on the MPS. Material requirement planning (MRP) can be used to determine the timing and quantities for all component and parts needed to manufacture the products.
- The back end phase encompasses systems for the execution of material and capacity plans. It deals with detailed scheduling and control of work centre activities on the shop floor and vendor scheduling. Orders are planned and released to the factory and vendors.

The planning framework is similar to the MPC framework. However, this framework has a clear focus on planning. While the measurement and control components are embedded in the MPC framework, the planning framework does not seem to take the measurement perspective into consideration. Yet, as the control concept often includes planning activities, the framework is here considered to be representative also for the control perspective.

The planning framework is divided into material and capacity planning perspectives. In the material perspective, planning deals with decisions regarding the deliveries in terms of product types, quantities and timing while in a capacity perspective, decisions regarding the capacity needed to produce required quantities and what capacity is available are dealt with. The planning framework is based on four levels:

- The sales and operations planning (SOP) cover the management process where overall plans for sales and production are established. Forecasting on tactical and operational levels seeks to foresee a future demand and is used for decisions regarding resource purchasing and utilisation as well as ongoing operations.
- In the master planning process, forecasts and customer orders constitute the information support. There are various customer order processes depending on product types and whether products are manufactured to stock or to orders. Master planning covers the process of establishing sales and production plans showing quantities of various product types that will produced over a time period.
- In order planning, the plans that have been defined on a strategic and tactical level are executed. It covers the administrative processes that are needed on an operational level to control material flows within a defined production and distribution structure.
- In workshop planning, production orders created on the superior levels are planned in detailed and executed. This planning seeks to establish a balance between available production capacity and current order and operations capacity needs.

With regard to the overall division, the time frame dimension is emphasised in both frameworks. In the MPC framework, the long term perspective includes management decisions regarding the appropriate amount of capacity to meet future market demands; in the intermediate term, activities deal with matching supply and demand in terms of product volume and mix; in the short term, focus is on detailed scheduling of resources to meet production requirements (Vollman et al., 2005). The planning framework takes besides the time frame dimension also the level of detail and decision levels into account; strategic, tactical and operational (Mattsson and Jonsson, 2003).

Both frameworks include the processes of SOP, master planning, material and capacity planning and workshop planning, although the processes are named differently. In the MPC framework, the master planning is divided into the same phase as SOP while in the planning framework, the master planning corresponds to a separate level. The front end of the MPC framework may correspond to the SOP and master planning levels of the planning framework, the engine phase to the order planning level and the back end phase to the workshop planning. The different planning levels can also be considered as main control processes covering a set of different sub-processes.

Information-sharing

The main control processes identified in the frameworks may imply sharing of different types of information both internally and with participants in the supply chain. In Table 1 below, some examples of such information types are presented based on the MPC and planning frameworks (Mattsson and Jonsson, 2003; Vollman et al., 2005). The time horizon shows the approximate planning time frame (Mattsson and Jonsson, 2003). However, it should be noted that these time frames may vary significantly among individual companies.

Table 1 - Examples of information types shared in main control processes

		Examples of information types shared	
Main control process	**Time horizon**	*Internally*	*In the supply chain*
Sales and operations planning	1-2 years	Demand forecasts Inventory levels Sales plans Delivery plans Production plans	Forecasts and/or order info. from customers Delivery plans to customers Production plans to suppliers
Master planning	6-12 months	Demand forecasts Inventory levels Delivery plans Production plans	Forecasts and/or order info. from customers Delivery plans to customers Production plans to suppliers
Material and capacity planning	2-6 months	Inventory levels Raw material levels Production order plans Purchase order plans	Forecasts and/or order info. from customers Info.on raw material levels to suppliers Info. on inventory levels to customers
Workshop and supplier planning	Daily/weekly	Raw materials levels Production orders	Purchase orders to supplier Order confirmation from supplier Invoices from/to supplier/customer

Forecasts and order information from customers constitute essential information in most levels for forecasting the future demand. As both customers and suppliers often are interested in forecasting their own activities, information such as delivery and production plans can also be shared in the supply chain. Information regarding inventory and raw material levels in stock may also be shared regularly with customers and suppliers. Exchange of information related to ordering and invoicing also involves customers and suppliers.

Automatic replenishment programs

A set of a new type of supply chain concepts with a focus on information-sharing and replenishment of materials and goods has emerged recently. These automatic replenishment programs (ARP) intend to increase the efficiency in inventory management by substituting inventory with information (Daugherty et al., 1999; Sabath et al., 2001). ARPs include those programs where replenishment is triggered by actual sales figures rather than on forecasts and safety stock buffers (Sabath et al., 2001). Examples of ARPs include industry specific programs such as efficient consumer response (ECR) and quick response (QR), continuous replenishment programs (CRP) where the buyer makes the replenishment decisions and vendor managed inventory (VMI) where the vendor is responsible (Sabath et al., 2001).

A specific initiative with a focus on information-sharing and replenishment is the so-called collaborative planning, forecasting and replenishment (CPFR) concept developed by the Voluntary Inter-industry Commerce Standards Association (VICS). In the CPFR framework, a number activities and tasks are defined that should be carried out jointly by suppliers and customers in the supply chain (Voluntary Industry Commerce Standards, 2004). The strategy and planning activity includes the establishment of an overall collaboration arrangement and a joint business plan; demand and supply management includes joint sales forecasting and order planning/forecasting; execution includes joint order generation and fulfilment; analysis includes that exception management and performance assessment is carried out jointly. Basically, the CPFR initiative encourages customers and suppliers in the supply chain to develop and apply joint forecasts and plans by sharing sales data, information about planned campaigns and sales and order forecasts (Mattsson, 2002).

In an overall perspective, ARPs are typically based on buyer-seller relationships where the seller uses information regarding product usage and inventory levels provided by the buyer to determine replenishment quantities, shipping and timing (Ellinger et al., 1999; Daugherty et al., 1999). However, relationships based on information-sharing related to ARPs and CPFR can take various forms in practice (Holweg et al., 2005). For example, customers and suppliers can order independently but exchange demand information and action plans in order to align forecasts for capacity and long-term planning. The replenishment decision can also be merged with production and materials planning of the supplier who is responsible for the customer's inventory replenishment on the operational level and uses the visibility in planning its own supply operations.

The literature indicates that information-sharing is a key component in supply chain control processes. Information that is used in control processes such as sales and operations planning and master planning can thus be exchanged and shared with participants to increase performance of the entire supply chain. Initiatives such as ARPs and CPFR further emphasise the role of information-sharing in the supply chain, supporting the physical replenishment process through joint planning and forecasting. Based on that information-sharing can be considered a key component for supply chains, there is a reason why ICT that supports information-sharing also can be considered an essential enabler of supply chain integration.

ICT AND SUPPLY CHAIN INTEGRATION

In this section, literature dealing with various dimensions and levels of supply chain integration is discussed together with research on the impact of ICT in a supply chain integration perspective.

Integration dimensions

The term integration can be generally defined as "the making up or composition of a whole by adding together or combining the separate parts or elements" (OED, 1989). A supply chain typically covers a series of activities from manufacturers to the retail stores defining a business process linking vendors, service providers and customers together (Council of Supply Chain Management Professionals, 2005). This implies that business process from manufacturing to retailing are combined, linking suppliers and customers together. As the process perspective is a central component, the adding or combining of activities and processes can be considered as an overall dimension for supply chain integration.

The process integration dimension is emphasised by several authors (Christopher, 1998; Bowersox et al., 1999; Frohlich and Westbrook, 2001). This dimension implies for instance the integration of processes, both internally and externally involving both upstream and downstream integration and the integration of the forward physical flow of deliveries between suppliers, manufacturers and customers. Process integration can refer to any collaborative working between buyers and suppliers.

Information integration is also recognised in research as an important dimension of supply chain integration (Davenport, 1993; Christopher, 1998; Bowersox et al., 1999; Lee, 2000; Frohlich and Westbrook, 2001). Information is often considered to be the glue that holds organisations together and can be used to integrate process activities both within a process and across multiple processes (Davenport, 1993). However, as information integration involves the backward coordination of information technologies and the flow of data from customers to suppliers, it differs from the integration of physical products which involves forward integration (Frohlich and Westbrook, 2001). Information integration is also closely related to the sharing of information and knowledge across the supply chain including for instance demand information, forecasting and replenishment (Lee, 2000) and is recognised as a central component in integration of planning and control (Bowersox et al., 1999).

Supply chain integration can refer to internal and external integration (Morash and Clinton, 1998; Bowersox et al., 1999; Campbell and Sankaran, 2005). In internal integration, focus is on the integration of a company's cross-functional processes within the firm for instance between production and logistics (Morash and Clinton, 1998; Campbell and Sankaran, 2005). In external or inter-organisational integration, focus is often on relationships with outside customers and suppliers, or forward and backward integration (Morash and Clinton, 1998; Bowersox et al., 1999; Campbell and Sankaran, 2005). External integration may also include operational integration such as optimising processes and material flows between companies (Morash and Clinton, 1998; Campbell and Sankaran, 2005).

Levels of integration

While the supply chain integration dimensions primarily set the scope of integration, the extent to which companies are integrated can be defined by studying the various levels of supply chain integration. Among trading partners, a relationship can have various intensity levels ranging from open-market negotiations, cooperation and coordination to collaboration (Tyndall et al., 1998) (Figure 2):

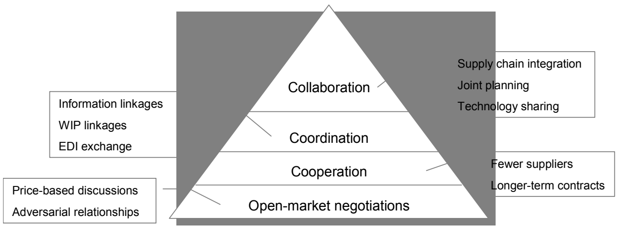

Figure 2 – Levels of supply chain integration (based on Tyndall et al., 1998).

The lowest level refers to open-market negotiations between independent customers and suppliers. The relationship connections are mainly concentrated to price discussions and there is basically no real integration between the trading companies. On the next level, companies exchange essential information and engage a few suppliers and customers in long-term contracts (Tyndall et al., 1998). Cooperation can be considered as any long-term agreement or understanding between independent organisations (Clemons and Row, 1992) and involve the joint execution of central activities (Bensaou, 1997). The level of coordination is focused to the exchange of specified activities and information to permit systems and mechanisms supporting the traditional linkages between trading companies (Tyndall et al., 1998). Collaboration often refers to the highest level of relationships intensity. It is based on a high degree of trust, commitment and information-sharing as companies become interdependent integrating activities and information flows across company boundaries (Tyndall et al., 1998). Collaboration also constitutes the level that best corresponds to true supply chain integration (Tyndall et al., 1998). For example, it can be achieved when operations of all companies in the supply chain are unified enabling optimisation of the entire supply chain (Campbell and Sankaran, 2005) or when several integration dimensions are integrated for instance information integration, coordination and organisational linkage (Lee, 2000). Furthermore, it is suggested that supply chain collaboration requires the linking of performance systems with decision synchronisation, information sharing and incentive alignment in the supply chain (Simatupang and Sridharan, 2005). Collaboration seems to be the most differentiated concept in literature as it is mainly used for higher levels of supply chain integration.

The impact of ICT

In this section, literature on the impact of ICT in a supply chain perspective is dealt with.

When studying effects of ICT in a supply chain integration perspective, it is important to consider that the supply chain often covers a wide range of different types of ICT. In an internal integration perspective, enterprise resource planning (ERP) systems are often recognised as essential ICT for supporting the internal sharing of information between functions and departments in an organisation. In an external integration perspective IOIS constituting automated information systems shared by two or more companies, can be used to support information-sharing with customers and suppliers (Kaufman, 1966; Barrett and Konsynski, 1982; Choudhury, 1997). The IOIS concept can be considered an overall term for a group of technologies that support information sharing across organisational boundaries as e-mail, electronic data interchange (EDI), extensible mark-up language (XML), electronic data access (EDA) and the Internet (Mattsson, 2002).

Overall effects of ICT in the supply chain are often expressed in terms of company performance such as efficiency and effectiveness (see for instance Stank et al., 2001; Kent and Mentzer, 2003; Sriram and Stump, 2004; Sanders and Premus, 2005). However, there are also many effects identified from the use of ICT in a supply chain perspective that are related to the relationships in the supply chain.

Effects of ICT related to the general quality and climate of the relationship including trust and commitment in the supply chain are often identified (Nidumolu, 1995; Hart and Saunders, 1997; Wilson and Vlosky, 1998; Kent and Mentzer, 2003; Sriram and Stump, 2004). In addition, ICT is considered to have a positive impact on both internal and external collaboration, and external collaboration is a further driver of internal collaboration (Stank et al., 2001; Sanders and Premus, 2005). ICT is also expected to contribute to improved communications patterns, an increased demand for coordination of joint activities and new organisational and societal structures through its ability to store, transmit and process information and speed up interorganisational activities (Clemons and Row, 1992, 1993; Nidumolu, 1995; Sriram and Stump, 2004).

There is a significant amount of research dealing with the impact of ICT in the supply chain that contributes to important insights to the different types of effects of ICT and the interdependencies of influencing factors. However, as there seems to be limited knowledge of the details in different settings involving different types of relationships that surround the actual contribution of ICT to integration, a research model for further investigation on the topic is proposed in the next section.

THE RESEARCH MODEL

Based on a review of literature within supply chain integration and the impact of ICT a research model is developed. The model is shown in Figure 3 below. The purpose is to provide further insights to the complex relation between ICT and integration of supply chain control. It can also be used as a starting point for empirical investigations within the field, defining the scope of the study or be used as an analytical framework. Furthermore, it proposes a set of areas that are considered to be relevant to take into consideration when exploring the impact of ICT on integration in supply chain control. The model primarily supports an overall explorative approach and is mainly adapted to in-depth qualitative studies such as case studies.

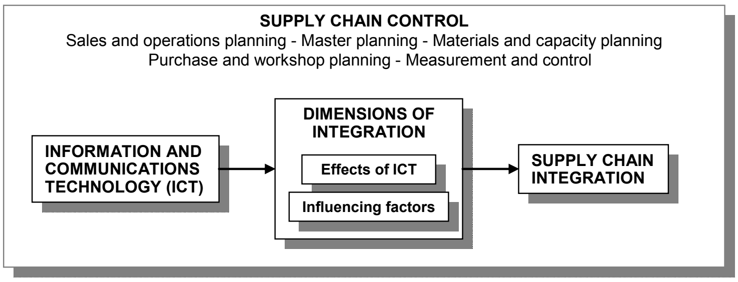

Figure 3 - The research model

The model consists of six areas; supply chain control, ICT, dimensions of integration, effects of ICT, influencing factors and supply chain integration.

The supply chain control area represents the surrounding context. Focus is on how ICT contributes to integration when it is used for information-sharing in supply chain control processes. Typically, these processes include four planning processes representing various time frames, detail and decision levels. Furthermore, a measurement and control process has been added to emphasise the control component in the context. Hence, both planning and control activities are included. This structure can be used when studying control activities in an empirical setting.

The ICT component of the model represents the use and adoption of different types of ICT used for information-sharing in the control context. The main focus is on external interorganisational aspects related to information-sharing across organisational boundaries in the supply chain. The internal intraorganisational perspective is included only to a limited extent. Examples of ICT that may be identified in an empirical study include the Internet, EDI and XML.

The impact of ICT can be expressed in terms of different dimensions of integration. There is emphasis on the process and information dimensions since these dimensions have a strong position through control processes and ICT in the model. However, other dimensions such as systems, technology and performance measurement may also be relevant to take into consideration for exploring the impact of ICT.

Within these integration dimensions, various effects of ICT are identified. These can be of both direct and more indirect character and include both effects related to performance such as measures of efficiency and effectiveness and other types of softer effects that are related to the relationship for instance. In addition, there are internal and external factors influencing the impact of ICT such characteristics of the market environment and of the relationship that also need to be taken into consideration.

These areas together form the basis for how ICT influences supply chain integration. The level of supply chain integration is defined based on the various integration dimensions and ICT effects. The type and level of integration may be expressed in terms of collaboration, coordination and cooperation and internal, external or supply chain activities. Integration may also be related to concepts such as ARP and CPFR.

CONCLUSIONS

This paper presents a research model that can be used to explore the impact of ICT on integration in supply chain control. It is developed based on literature within supply chain integration and the impact of ICT in a supply chain perspective. Literature dealing with supply chain control has also been used. The model incorporates a set of control processes and covers a number of areas that are relevant when exploring the impact of ICT on integration. These areas include the types of ICT applied for information-sharing, various dimensions of integration, different effects of ICT and factors influencing the impact and the supply chain integration area.

This research contributes with further insights to the complex relation between ICT and supply chain integration. From a research point of view, the model gives an overview of certain areas that are important to take into consideration when studying the phenomenon. It also provides support for researchers who want to further investigate the impact of ICT. Furthermore, the model may be used by practitioners seeking to understand how ICT influences the integration of certain supply chains of individual firms.

As the model is based on only a limited selection of a considerable amount of literature, it can be further developed from a more comprehensive literature review. It can also be further developed from empirical testing based on a set of brief case studies for example. Furthermore, the model can be used throughout the entire process of empirical investigations, for defining the overall scope of studies, setting the frames of data collection or as an analytical framework.

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