TKK Dissertations 98
Espoo 2007

XML-BASED E-BUSINESS FRAMEWORKS AND SUPPLY CHAIN INTEGRATION

Doctoral Dissertation

Juha-Miikka Nurmilaakso

Helsinki University of Technology
Department of Computer Science and Engineering
Software Business and Engineering Institute

TKK Dissertations 98
Espoo 2007

XML-BASED E-BUSINESS FRAMEWORKS AND SUPPLY CHAIN INTEGRATION

Doctoral Dissertation

Juha-Miikka Nurmilaakso

Dissertation for the degree of Doctor of Science in Technology to be presented with due permission of the Department of Computer Science and Engineering for public examination and debate in Auditorium TU1 at Helsinki University of Technology (Espoo, Finland) on the 3rd of December, 2007, at 13 o'clock.

Helsinki University of Technology
Department of Computer Science and Engineering
Software Business and Engineering Institute

Teknillinen korkeakoulu
Tietotekniikan osasto
Ohjelmistoliiketoiminnan ja -tuotannon laboratorio

Distribution:
Helsinki University of Technology
Department of Computer Science and Engineering
Software Business and Engineering Institute
P.O. Box 9210
FI - 02015 TKK
FINLAND
URL: http://www.soberit.tkk.fi/
Tel. +358-9-4511
Fax +358-9-451 4958
E-mail: reports@soberit.tkk.fi

ISBN 978-951-22-9073-4
ISBN 978-951-22-9074-1 (PDF)
ISSN 1795-2239
ISSN 1795-4584 (PDF)
URL: http://lib.tkk.fi/Diss/2007/isbn9789512290741/

TKK-DISS-2379

Multiprint Oy
Espoo 2007

ABSTRACT OF DOCTORAL DISSERTATION	HELSINKI UNIVERSITY OF TECHNOLOGY P.O. BOX 1000, FI-02015 TKK http://www.tkk.fi

Author Juha-Miikka Nurmilaakso

Name of the dissertation
XML-based E-business Frameworks and Supply Chain Integration

Manuscript submitted 12.9.2006	Manuscript revised 17.10.2007
Date of the defence 3.12.2007	
☐ Monograph	☒ Article dissertation (summary + original articles)

Department	Department of Computer Science and Engineering
Laboratory	Software Business and Engineering Institute
Field of research	Electronic Business
Opponent	Professor Airi Salminen
Supervisor	Professor Reijo Sulonen
Instructor	Professor Reijo Sulonen

Abstract

Although information and communication technologies have opened up new possibilities of doing business, supply chain integration, especially exchange of business documents in business processes, is far from simple. Fortunately, standardization can facilitate information sharing between business partners. Data formats, such as XML, are low-level standards that define data structures and data elements. They are insufficient in supply chain integration because business partners must know what information should be shared when and how. E-business frameworks are high-level standards that specify business documents, business processes and messaging. XML-based e-business frameworks are limitedly open and have been mostly standardized in formal organizations. In addition, industry-specific e-business frameworks seem to be more comprehensive in their properties than cross-industry e-business frameworks. Software vendors tend to prefer the standardization of cross-industry e-business frameworks, whereas users tend to favor the standardization of industry-specific e-business frameworks.

Within an industrial case, an XML-based integration system prototype proved that the XML format and basic XML technologies, together with an e-business framework, provide a sound basis for supply chain integration. According to this industrial case, XML-based integration systems can result in cost savings in comparison to EDI-based integration systems.

The XML format has gained a significant footing in industry-specific e-business frameworks and dominates in cross-industry-process e-business frameworks. The use of XML-based e-business frameworks has increased more than the use of EDI-based e-business frameworks in 2004. In addition, the use of XML-based e-business frameworks has become more common in the new European market economies and in those industries for which there is an XML-based but no EDI-based industry-specific e-business framework. XML-based e-business frameworks seem to support a larger number of e-business functions than EDI-based e-business frameworks. If the company has adopted a large number of e-business functions, it will more likely replace EDI-based with XML-based e-business frameworks.

Keywords electronic business (e-business), supply chains, information sharing, standardization, integration systems, Extensible Markup Language (XML), Electronic Data Interchange (EDI)

ISBN (printed) 978-951-22-9073-4	ISSN (printed) 1795-2239
ISBN (pdf) 978-951-22-9074-1	ISSN (pdf) 1795-4584
Language English	Number of pages 85 + 72 (original articles)
Publisher Multiprint Oy	
Print distribution TKK / Software Business and Engineering Institute	

☒ The dissertation can be read at http://lib.tkk.fi/Diss/2007/isbn9789512290741/

VÄITÖSKIRJAN TIIVISTELMÄ	TEKNILLINEN KORKEAKOULU PL 1000, 02015 TKK http://www.tkk.fi

Tekijä Juha-Miikka Nurmilaakso

Väitöskirjan nimi
XML-pohjaiset sähköisen liiketoiminnan kehikot ja toimitusketjun integraatio

Käsikirjoituksen päivämäärä 12.9.2006	Korjatun käsikirjoituksen päivämäärä 17.10.2007

Väitöstilaisuuden ajankohta 3.12.2007

☐ Monografia	☒ Yhdistelmäväitöskirja (yhteenveto + erillisartikkelit)

Osasto	Tietotekniikan osasto
Laboratorio	Ohjelmistoliiketoiminnan ja –tuotannon laboratorio
Tutkimusala	Sähköinen liiketoiminta
Vastaväittäjä	Professori Airi Salminen
Työn valvoja	Professori Reijo Sulonen
Työn ohjaaja	Professori Reijo Sulonen

Tiivistelmä

Tieto- ja viestintätekniikat ovat avanneet uusia mahdollisuuksia tehdä liiketoimintaa. Kuitenkin toimitusketjun integraatio erityisesti liiketoimintadokumenttien vaihtamiseksi liikekumppanien välisissä liiketoimintaprosesseissa ei ole yksinkertaista. Onneksi standardointi helpottaa tiedon jakamista kumppanien välillä. Tietoformaatit kuten XML ovat alemman tason standardeja, jotka määrittelevät tiedon rakenteet ja osat yleisesti. Formaatit ovat riittämättömiä integraatiossa, koska kumppanien on tiedettävä mitä tietoa pitää jakaa milloin ja miten. Sähköisen liiketoiminnan kehikot ovat korkean tason standardeja, jotka määrittelevät dokumentteja, prosesseja ja viestintätapoja liiketoimintaan. XML-pohjaiset kehikot ovat tekijänoikeudellisesti rajallisesti avoimia ja standardoitu useimmiten tarkoitusta varten muodostetuissa organisaatioissa. Toimialakohtaiset kehikot näyttävät olevan ominaisuuksiltaan laajempia kuin toimialariippumattomat kehikot. Ohjelmistoyrityksillä on tapana suosia toimialariippumattomien kehikoiden ja käyttäjäyrityksillä toimialakohtaisten kehikoiden standardointia.

Teollisen tapaustutkimuksen puitteissa XML-pohjaisen integraatiojärjestelmän prototyyppi osoitti, että XML-formaatti ja –tekniikat yhdessä kehikon kanssa tarjoavat hyvän perustan integraatiolle. Tämän tapaustutkimuksen mukaan XML-pohjaiset integraatiojärjestelmät voivat tuottaa kustannussäästöjä verrattuna EDI-pohjaisiin integraatiojärjestelmiin.

XML-formaatti on saavuttanut merkittävän aseman toimialakohtaisissa kehikoissa ja on hallitseva prosesseihin painottuvissa toimialariippumattomissa kehikoissa. XML-pohjaisten kehikoiden käyttö on lisääntynyt enemmän kuin EDI-pohjaisten kehikoiden käyttö vuonna 2004. Lisäksi XML-pohjaisen kehikot ovat tulleet yleisemmiksi kuin EDI-pohjaiset kehikot niissä eurooppalaisissa maissa, jotka ovat uusia markkinatalouksia, sekä niillä toimialoilla, joita varten on olemassa XML-pohjainen mutta ei EDI-pohjaista toimialakohtaista kehikkoa. XML-pohjaiset kehikot näyttävät tukevan useampia sähköisiä liiketoimintoja kuin EDI-pohjaiset kehikot. Yritys on suuremmalla todennäköisyydellä valmis korvaamaan EDI-pohjaiset XML-pohjaisilla kehikoilla, jos se on omaksunut useita sähköisiä liiketoimintoja.

Asiasanat sähköinen liiketoiminta, toimitusketjut, tiedon jakaminen, standardointi, integraatiojärjestelmät, Extensible Markup Language (XML), Electronic Data Interchange (EDI)

ISBN (painettu) 978-951-22-9073-4	ISSN (painettu) 1795-2239
ISBN (pdf) 978-951-22-9074-1	ISSN (pdf) 1795-4584
Kieli Englanti	Sivumäärä 85 + 72 (erillisartikkelit)

Julkaisija Multiprint Oy

Painetun väitöskirjan jakelu TKK / Ohjelmistoliiketoiminnan ja –tuotannon laboratorio

☒ Luettavissa verkossa osoitteessa http://lib.tkk.fi/Diss/2007/isbn9789512290741/

Acknowledgements

This thesis was started at the Production and Operation Management Group, Technical Research Centre of Finland. The ground work was done in the IST Project GNOSIS-VF: Towards the Virtual Factory: Delivering Configuration, Scheduling and Monitoring Services through a Web-based Client-server Architecture, which was funded partly by the European Commission. I thank Jari Kettunen and Ilkka Seilonen as well as ABB Control and InCap Electronics for their cooperation in this project.

The thesis was finished at the Product Data Management Group, Helsinki University of Technology. The work was funded by the Graduate School for Electronic Business and Software Industry, which is gratefully acknowledged. I am indebted to Paavo Kotinurmi and Hannu Laesvuori for their valuable cooperation and acknowledge e-Business W@tch and the European Commission for e-business survey data. I would also like to thank Professor Reijo Sulonen for his supervision, Professor Peter Buxmann from Technical University of Darmstadt, Professor Matti Rossi from Helsinki School of Economics and Docent Timo Soininen for their comments.

My friends, and especially my family, have encouraged and supported me. I am very grateful to them. Thank you all!

“Technical and economic viability should be regarded as a constraint rather than as an objective.”

Helsinki, November 2007

Juha Nurmilaakso

To Eila and Lyyli

Table of contents

List of publications

This thesis consists of an overview and of the following five publications, which are referred to in the text by their Roman numerals:

I Nurmilaakso, J.M., Kotinurmi, P., 2004, "A review of XML-based supply-chain integration", *Production Planning & Control*, Vol. 15, No. 6, pp. 608-621.

Publication (I) introduces XML technologies, identifies the basic properties of e-business frameworks by analyzing 23 XML-based e-business frameworks, compares eight of them and summarizes experiences from XML-based supply chain integration. The author of this thesis was mainly responsible for the basic definition and properties of the XML-based e-business frameworks, the comparison of these e-business frameworks and the experiences from XML-based supply chain integration. The second author (Paavo Kotinurmi) was mainly responsible for the overview of XML technologies.

II Nurmilaakso, J.M., Kettunen, J., Seilonen, I., 2002, "XML-based supply chain integration: a case study", *Integrated Manufacturing Systems*, Vol. 13, No. 8, pp. 586-595.

Publication (II) describes an XML-based integration system prototype evaluated against an EDI-base integration system in an industrial case. The author of this thesis designed the prototype with the third author (Ilkka Seilonen) and implemented the integration system prototype. The second author (Jari Kettunen) was the principal evaluator of the prototype.

III Nurmilaakso, J.M., Kotinurmi, P., Laesvuori, H., 2006, "XML-based e-business frameworks and standardization", *Computer Standards & Interfaces*, Vol. 28, No. 5, pp. 585-599.

Publication (III) analyzes 12 XML-based e-business frameworks to identify and explain the commonalities, differences and regularities between these e-business frameworks and their standardization. The author of this thesis contributed the standardization of XML-based e-business frameworks as well as their commonalities. In addition, the author was mainly responsible for the differences and regularities. The second author (Paavo Kotinurmi) was mainly responsible for the extended definition and properties of the XML-based e-business frameworks. The third author (Hannu Laesvuori) participated in introducing XML-based e-business frameworks.

IV Nurmilaakso, J.M., 2007, "EDI, XML and e-business frameworks: a survey", *Computers in Industry*, accepted for publication.

Publication (IV) compares the use of the ASC X12, EDIFACT and XML formats in 38 e-business frameworks and the use of EDI-based and XML-based e-business frameworks in 7593 European companies. This publication also discusses a lock-in to the EDI formats in e-business frameworks and to EDI-based e-business frameworks in companies. The author of this thesis was responsible for the publication.

V Nurmilaakso, J.M., 2007, “Adoption of e-business functions and migration from EDI-based to XML-based e-business frameworks in supply chain integration”, *International Journal of Production Economics*, accepted for publication.

Publication (V) explores how organizational and technological factors, including EDI-based and XML-based e-business frameworks, explain the adoption of e-business functions in 4570 European companies and the migration from EDI-based to XML-based e-business frameworks in 329 European companies. The author of this thesis was responsible for this publication also.

List of abbreviations

2A1	Distribute Product Catalog Information
2A10	Distribute Design Engineering Information
2C5	Notify of Engineering Change Order
3A4	Request Purchase Order
3A6	Distribute Order Status
3A7	Notify of Purchase Order Update
3A8	Request Purchase Order Change
3A9	Request Purchase Order Cancellation
3B2	Notify of Advance Shipment
3C3	Notify of Invoice
3C6	Notify of Remittance Advice
4A3	Notify of Threshold Release Forecast
4A4	Notify of Planning Release Forecast
4A5	Notify of Forecast Reply
4B2	Notify of Shipment Receipt
4C1	Distribute Inventory Report
5D1	Request Ship from Stock and Debit Authorization
ACORD	Association for Cooperative Operations Research and Development
AIAG	Automotive Industry Action Group
ANSI	American National Standards Institute
ASC X12	Accredited Standards Committee X12
B2B	Business-to-business
B2C	Business-to-consumer

B2G	Business-to-government
BPEL	Business Process Execution Language
BPML	Business Process Modeling Language
BPSS	ebXML Business Process Specification Schema
CA	Communication Application
CATI	Computer-aided Telephone Interview
CBL	Common Business Library
CCTS	ebXML Core Component Technical Specification
CEFACT	UN for Trade Facilitation and Electronic Business
CIAG	Construction Industry Action Group
CICA	Context Inspired Component Architecture
CIDX	Chemical Industry Data Exchange
COPIS	Customer-oriented Process Information System
CRM	Customer Relationship Management
cXML	Commerce XML
DSK	Dvorak Simplified Keyboard
DTD	Document Type Definition
EAI	Enterprise Application Integration
EBNF	Extended Backus-Naur Form
E-business	Electronic Business
ebXML	E-business XML
E-commerce	Electronic Commerce
EDI	Electronic Data Interchange
EDIFACT	EDI for Administration, Commerce and Transportation
EDIFICE	EDI Forum for Companies with Interests in Computing and Electronics
EDIINT	EDI Internet Integration

EIDX	Electronics Industry Data Exchange
ERP	Enterprise Resource Planning
ESIDEL	European Steel Industry Data Exchange Language
FIX	Financial Information Exchange
FIXML	FIX Markup Language
GCA	Graphic Communications Association
GML	Generalized Markup Language
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
ICT	Information and Communication Technology
IETF	Internet Engineering Task Force
IFX	Interactive Financial Exchange
IPR	Intellectual Property Right
ISO	International Organization for Standardization
ITO	Inventory Turnover
J2SE	Java 2 Platform Standard Edition
JAXP	Java Application Programming Interface for XML Processing
MG	RosettaNet Message Guideline
MIME	Multipurpose Internet Mail Extensions
MODA-ML	Middleware Tools and Documents to Enhance the Textile/Clothing Supply Chain through XML
MRP	Material Requirements Planning
MSG	ebXML Messaging Services
PIDX	Petroleum Industry Data Exchange
PIP	RosettaNet Partner Interface Process
OAGIS	Open Applications Group Integration Specification

OASIS	Organization for the Advancement of Structured Information Standards
ODBC	Open Database Connectivity
ODETTE	Organization for Data Exchange by Teletransmission in Europe
OFX	Open Financial Exchange
OLS	Ordinary Least Squares
OWL	Web Ontology Language
RDF	Resource Description Framework
RDFS	RDF Schema
RINET	Reinsurance and Insurance Network
RNBD	RosettaNet Business Dictionary
RNIF	RosettaNet Implementation Framework
RNTD	RosettaNet Technical Dictionary
SCM	Supply Chain Management
SCOR	Supply Chain Operations Reference
SDO	Standards Developing Organization
SGML	Standard GML
SME	Small and Medium-sized Enterprise
S/MIME	Security Multiparts for MIME
SMTP	Simple Mail Transfer Protocol
SOAP	Simple Object Access Protocol
SQL	Standard Query Language
STEP	Standard Exchange for Product Data
SWIFT	Society for Worldwide Interbank Financial Telecommunication
swiftML	SWIFT Markup Language
TDCC	Transportation Data Coordinating Committee
TRADACOMS	Trading Data Communications

UBL	Universal Business Language
UCS	Uniform Communication Standard
UDDI	Universal Description, Discovery and Integration
UNECE	UN Economic Commission for Europe
VAN	Value-added Network
VCML	Value Chain Markup Language
VICS	Voluntary Interindustry Commerce Standard
VIF	Variance Inflation Factor
W3C	World Wide Web Consortium
WSDL	Web Services Definition Language
xCBL	XML CBL
XML	Extensible Markup Language
XPDL	XML Process Description Language
XSD	XML Schema Definition
XSLT	Extensible Stylesheet Language Transformations

1 Introduction

This section introduces the background, research questions, contributions and structure of the thesis. Subsection 1.1 takes a brief look at information sharing in supply chains and standards for e-business. This subsection also introduces the key concepts and motivation of the thesis. Subsection 1.2 presents the two research questions that the five publications aim to answer. Subsection 1.3 summarizes the contributions of the thesis. Finally, subsection 1.4 gives the structure of the rest of this thesis.

1.1 Background

Information and communication technologies (ICT) have a significant effect on how companies do business (Brynjolfsson and Hitt 2000, Gurbaxani and Whang 1991, Malone et al. 1987). Since the 1980s, supply chain management (SCM) has received the attention of practitioners and academics. A *supply chain* is a bidirectional flow of products, information and money between the initial suppliers and final customers through different organizations (Cooper et al. 1997). *SCM* is about planning, implementing and controlling this flow (Wacker 2004). For example, its goal can be to improve organizational competitiveness. The supply chain, particularly SCM, contains different business functions, such as sales, purchases, demand forecasting and resource management. Supply chain integration is an important part of SCM. It strives to ease the flow between all organizations in the supply chain (Naylor et al. 1999). *Supply chain integration* is fundamentally about information sharing within and between companies. In this thesis, *information sharing* mainly refers to the exchange of business documents in business processes. For example, inaccurate or late information on purchase orders, demand forecasts or production schedules can lead to inefficiencies in the supply chains. Supply chain integration attempts to make relevant, accurate and timely information available to the decision makers (Lee 2000). Companies are increasingly aware of the strategic importance of supply chain integration because it affects operational performance (Bagchi et al. 2005).

Since the 1960s, companies have used information systems and electronic exchange of data with their customers and suppliers (Hayes 2002). First, this development focused on *Electronic Data Interchange* (EDI), which is the interorganizational exchange of business documents in a machine-processable format (Emmelhainz 1990). Next, the development turned towards *electronic commerce* (e-commerce), in which companies utilize ICTs, especially computer-mediated networks, in the selling and buying of products (Gunasekaran et al. 2002, Laudon and Laudon 2006). E-commerce focuses on online sales and purchases. There are several models of e-commerce, namely, b*usiness-to-business* (B2B) e-commerce between companies, *business-to-consumer* (B2C) e-commerce between companies and consumers, and *business-to-government* (B2G) e-commerce between companies and government organizations. Now, B2B e-commerce has widened into *electronic business* (e-business), in which companies utilize ICTs in all kinds of business interactions with their business partners (Laudon and Laudon

2006). E-business does not cover only online sales and purchases but also, for example, online demand forecasting and resource management. Supply chain integration and e-business are interrelated in business interactions. An e-business function, such as online sales, purchases, demand forecasting or resource management, is a business function in the supply chain, in which a company shares information with its business partners through computer-mediated networks, such as value-added networks (VAN) or Internet.

With the rising interest in e-business, the significance of information sharing has grown. Information systems have a tremendous influence on achieving effective SCM (Gunasekaran and Ngai 2004). Companies have invested heavily in ICTs, particularly in enterprise resource planning (ERP), SCM and customer relationship management (CRM) systems (Falk 2005). For example, the electronic exchange of business documents can reduce printing and re-keying the data (Emmelhainz 1990). Therefore, *automated* business interactions, i.e. business interactions using ICTs, can be quicker and more accurate than *manual* business interactions, i.e. business interactions by meetings, mail, phone calls, faxes or e-mails. There is a large variety of automation initiatives ranging from simple business interactions between organizational units within a company to complex business interactions between companies in a supply chain network. Unfortunately, it is not easy to automate business interactions due to the differences between any two business partners, as the following examples illustrate:

- The product quantity unit may mean “pieces” in manufacturing industries but “hours” in services industries. Similarly, a US company may use “USD” but an EU company “EUR” in pricing.

- One company may manage its operations through orders, i.e. make-to-order or engineer-to-order, and another through inventories, i.e. make-to-stock or make-to-assembly. These practices can change depending on the business cycles, which affect different industries and countries in different magnitudes and phases.

- A company may have a packaged ERP system, whereas its business partner uses an in-house ERP system. Similarly, a company may have a SCM but no CRM system, whereas its business partner uses a CRM but no SCM system.

In the supply chains, the information systems need to work with other internal and external information systems. There would be fewer problems in supply chain integration, especially in exchange of business documents in business processes, if all organizations used similar meanings for terms in the business documents, similar modes of operations in the business processes and the same messaging interfaces in the information systems. Companies and their organizational units may establish “islands of automation”, which means that data cannot flow between their information systems. If information systems are not interoperable, human intervention is needed to prepare the input data for the information systems to produce the output data. Although differences are often inevitable, the lack of interoperability can cause significant costs.

There is a need for developing standards for information systems in SCM (Gunasekaran and Ngai 2004). One way of facilitating supply chain integration is to apply standards that enable information sharing between business partners. Standardization can bring order into complexity and uncertainty by reducing the variety. Standards have played an important role in the evolution of ICT (Lyytinen and King 2006). Standards are also important in the development of e-business. Standardization for e-business happens on two levels. A *data format* is a low-level standard that defines the data structures and data elements in general. An *e-business framework* is a high-level standard that uses a data format to specify the data structures, data elements and their purposes in the business context. The e-business frameworks support interoperability by harmonizing the meanings for terms and the modes of operations and standardizing the messaging interfaces. They can enable information sharing with lower implementation and operating costs. American National Standards Institute (ANSI) Accredited Standards Committee (ASC) X12 (ANSI 2005) and UN Economic Commission for Europe (UNECE) EDI for Administration, Commerce and Transportation (EDIFACT) (UNECE 2005) are well-known standards. ASC X12 and EDIFACT are data formats as well as e-business frameworks. In this thesis, EDI-based e-business frameworks have been standardized to utilize the ASC X12 or EDIFACT format. Standard Generalized Markup Language (SGML) and Hypertext Markup Language (HTML) have resulted in *Extensible Markup Language* (XML) (W3C 2004) that is a data format as well as a metalanguage for electronic document management and web publishing. Tim Bray, a co-author of XML, has claimed that “XML is the ASCII of the future”. Tens of e-business frameworks, such as XML Common Business Library (xCBL) (Commerce One 2004) and RosettaNet (2004), have been standardized to utilize the XML format.

What motivates this thesis? From the academic viewpoint, there are deficiencies in the research related to the XML format, e-business frameworks and supply chain integration. XML-based supply chain integration has not been studied as extensively as EDI-based supply chain integration (Elgarah et al. 2005). There is a small number of papers reporting experiences from XML-based supply chain integration (e.g. Chiu and Chen 2005, Lu et al. 2006, Kotinurmi et al. 2004, Yen et al. 2004). In addition, it can be difficult to find papers describing standards for e-business (Ngai and Wat 2002) or studying the adoption of ICT standards (Morell 1994). Despite considerable interest in e-business and SCM, the literature studies (e.g. Power 2005, Wareham et al. 2005) reveal gaps in the understanding of the use of e-business frameworks. Economic analyses of the role of XML in e-business are missing (Kauffman and Walden 2001). Research on ICT standardization is also lacking (Lyytinen and King 2006). Some papers deal with the e-business-related adoption or migration (e.g. Zhu et al. 2003, 2006) but only few papers compare the properties of e-business frameworks (e.g. Medjahed et al. 2003, Shim et al. 2000) or analyze their standardization (e.g. Nelson et al. 2005). Moreover, many papers regard XML as more efficient than EDI (e.g. Hsieh and Lin 2004, Reimers 2001), whereas the benefits of XML do not outweigh its costs according to some papers (e.g. Kanakamedala et al. 2003). There are economic arguments both for (David 1985, Katz and Shapiro 1986) and against (Liebowitz and Margolis 1990, 1995) an older non-proprietary technology having an advantage over a newer non-proprietary technology. If this advantage were true, the EDI formats should dominate the XML format in e-business.

From the practical viewpoint, XML has received significant attention. A number of standards developing organizations (SDO) and companies have shown great interest in

XML-based e-business frameworks and supply chain integration. For example, Microsoft (2002) has developed and Nokia (Auramo et al. 2005) uses an XML-based integration system. These companies are also involved in the standardization of an XML-based e-business framework (RosettaNet 2004). Many are convinced that XML will be "the ASCII of e-business" (Economist 2001). There are a large number of e-business frameworks that causes confusion as to which e-business framework should be supported, if any. It is difficult to know to the extent to which any particular e-business framework satisfies the needs for supply chain integration. Different e-business frameworks are not necessarily interoperable. Especially XML-based e-business frameworks differ from EDI-based e-business frameworks. How the e-business framework is standardized may also affect the outcome.

1.2 Research questions

The thesis strives to enhance the knowledge of XML format, e-business frameworks and supply chain integration. This knowledge can be useful for both the researchers of ICT standards or supply chain integration and the developers and users of e-business frameworks or integration systems. This thesis aims to evaluate the feasibility of a new solution, i.e. XML-based e-business frameworks, and its advantages over an old solution, i.e. EDI-based e-business frameworks, to a problem, i.e. supply chain integration. The thesis answers two research questions:

1. *How do XML and e-business frameworks support supply chain integration?* This requires an overview of experiences from XML-based supply chain integration. An XML-based integration system should be designed and implemented and its feasibility should be evaluated within an industrial case. In addition, the purpose of XML and e-business frameworks should be explained and the basic properties of e-business frameworks should be identified. Moreover, it is important to analyze the relationships between these properties and the standardization of XML-based e-business frameworks. The first question is addressed in publications (I), (II) and (III). Seilonen et al. (2001) and Kotinurmi et al. (2003) also study this question.

2. *Compared to EDI-based e-business frameworks, what kind of a role do XML-based e-business frameworks play in supply chain integration?* The benefits and costs of the XML-based integration system should be compared to the benefits and costs of an EDI-based integration system within an industrial case. Considering standardization, the use of the EDI and XML formats in e-business frameworks is compared. In addition, it is necessary to analyze the use of EDI-based and XML-based e-business frameworks in companies, their effects among other factors on the adoption of e-business functions in supply chain integration and factors affecting the migration from EDI-based to XML-based e-business frameworks in supply chain integration. This second question is addressed in publications (II), (IV) and (V). Nurmilaakso et al. (2001) also investigate this question.

The thesis stresses the technical aspects of data formats, e-business frameworks and supply chain integration but does not ignore their business aspects. E-business frameworks and integration systems are not black boxes; they include technological factors. E-business frameworks are not standardized in and integration systems are not used by black boxes; their standardization and use depends on economic and organizational factors. Therefore, this thesis is not limited to computer science and industrial engineering but is also influenced by economics and information systems science.

The thesis faced three major difficulties. Firstly, there is no consensus over the definition of e-business, EDI, SCM and supply chain integration (e.g. Ngai and Wat 2002, Tan 2001). This difficulty occurs in the literature-related parts of the thesis. Secondly, the most appropriate research data are not available for both research questions. Thirdly, no individual analysis method alone is suited for studying both research questions. Therefore, qualitative and quantitative analysis methods were applied. The research data were based on software prototypes, case companies, technical specifications, historical records and statistics. For these reasons, the content of the thesis is not as coherent as it might otherwise be.

1.3 Contributions

This thesis makes three empirical contributions. The first contribution is the identification of the basic properties of XML-based e-business frameworks and their relationships to standardization. The properties are discussed mostly in publication (I) and the relationships in publication (III). XML-based e-business frameworks do not specify only business documents but also business processes and messaging. Moreover, whether software vendors or users are mainly participants in standardization influences the properties of the XML-based e-business framework.

The second contribution is based on the development of an XML-based integration system and its evaluation against an EDI-based integration system. Publication (II) is among the first academic studies in which an integration system prototype utilizes XML in business documents and the configuration of business interactions. The benefits and costs of this prototype and an EDI-based integration system are compared within a real case. The integration system prototype was extended twice and all three versions of the prototype satisfied the requirements. This supported the feasibility of XML-based supply chain integration in the real case. xCBL was used as an e-business framework in the XML-based integration system prototype and EDIFACT in the EDI-based integration system. Although xCBL and EDIFACT were similar, XML-based supply chain integration had advantages over EDI-based supply chain integration in this real case.

The third contribution is the statistical analyses of the use of EDI-based and XML-based e-business frameworks and the migration from EDI-based to XML-based e-business frameworks. Publications (IV) and (V) challenge some well-known findings presented in the literature. There is no significant lock-in to the EDI formats and EDI-based e-business frameworks. The use of the EDI formats and XML-based e-business frameworks has not blocked the adoption of the XML format and XML-based e-business frameworks. This is hardly possible if the XML format and XML-based e-business frameworks have no advantages over the EDI formats and EDI-based e-business frameworks. Technological factors mainly affect the adoption of e-business functions. XML-based e-business frameworks facilitate even more this adoption than EDI-based e-business frameworks. Organizational factors play a primary role in the migration from EDI-based to XML-based e-business frameworks. The number of e-business functions facilitates and the VAN usage does not inhibit this migration.

1.4 Structure

Section 2 provides an introduction to SCM, supply chain integration, data formats and e-business frameworks. It also covers the literature on standards, standardization and experiences from EDI-based and XML-based supply chain integration. This section is mainly based on publication (I). In addition, subsection 2.1 is based on publication (V), subsections 2.2 publications (III) and (IV) and subsection 2.3 on publications (III), (IV) and (V). Section 3 addresses the results of the thesis. Subsection 3.1 reports the implementation of an XML-based integration system prototype as well as its evaluation in an industrial case (II). Subsection 3.2 deals with the properties and standardization of XML-based e-business frameworks (III). Subsection 3.3 compares the use of EDI and XML formats in e-business frameworks and the use of these e-business frameworks in companies (IV). Subsection 3.4 explores the adoption of e-business functions and the migration from EDI-based to XML-based e-business frameworks in supply chain integration (V). Section 4 assesses the validity and reliability of the results, compares these results with previous research and proposes research ideas for further research. Section 5 concludes the thesis.

2 Review

This section introduces XML, e-business frameworks and supply chain integration. Without information sharing within and between companies, a supply chain can be in serious problems. Supply chain integration is a necessary rather than a sufficient requirement for efficient SCM. Although data formats facilitate information sharing, e-business frameworks are often needed. This section starts from the problem domain, proceeds through the solution domains and ends with the related literature. Subsection 2.1 discusses SCM and supply chain integration. Subsection 2.2 provides an introduction to the ASC X12, EDIFACT and XML formats. It also defines and discusses e-business frameworks, their purpose and basic properties (I). This is one of the results of the thesis. Subsection 2.3 reviews the literature and discusses the obvious limitations of this literature. The focus is directed to the most notable theoretical and empirical findings on standards, standardization and XML-based e-business frameworks as well as experiences from EDI-based and XML-based supply chain integration.

2.1 Supply chains

2.1.1 Supply chain management

Before products can flow from the initial suppliers to the final customers and money from the final customers to the initial suppliers, the business partners have to share information. The business partners are not only different companies. They are often different organizational units within the same company. Figure 1 indicates how a bidirectional flow of information, products and money is related to the external and internal supply chain.

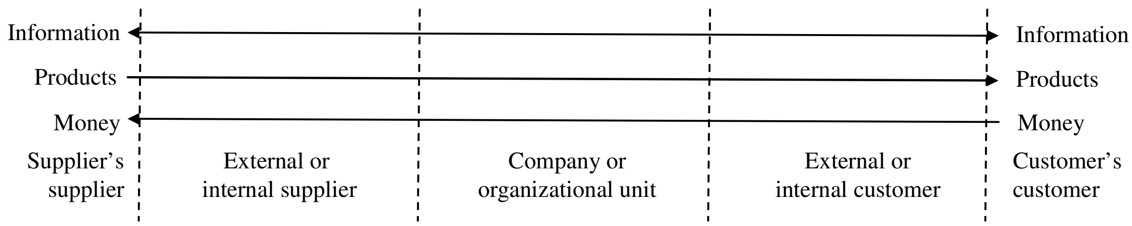

Figure 1: A bidirectional flow of information, products and money

A supply chain is closely related to Porter's (1985) idea of a value chain that is based on the process view of organizations. According to the value chain, an organization can be seen as a system that is made up of subsystems, each with inputs, transformation processes and outputs. Without a loss of generality, the supply chain is a bidirectional flow of products, information and money between the initial suppliers and final customers through different organizations. These organizations can be autonomous companies, subsidiary companies and identifiable organizational units.

The term SCM is not unambiguous but it is a more comprehensive concept than logistics (Cooper et al. 1997). In addition, the terms value chain management (Porter 1985) and demand chain management (Frohlich and Westbrook 2002) have been used in a similar context to SCM. According to Lambert et al. (1998), SCM is defined as the integration of key business processes from an end user through original suppliers that provides products, services and information and add value for customers and other stakeholders. Simchi-Levi et al. (2000) state that SCM is a set of approaches utilized to effectively integrate suppliers, manufacturers, warehouses and stores so that merchandise is produced and distributed in the right quantities, to the right locations and at the right time to minimize total system cost subject to satisfying service requirements. Tan (2001) argues that three distinct descriptions of SCM dominate in the literature and overlap in some cases. Firstly, SCM may be used to describe the purchasing and supply activities of the manufacturers. Secondly, it may be used to describe the transportation and logistics activities of the wholesalers and retailers. Thirdly, SCM may be used to describe all the value-adding activities from the raw materials extractors to the end users. Wacker (2004) has developed a formal conceptual definition of SCM for academic empirical research. According to this definition, SCM means the plan, control and implementation of the movement of goods and services from the initial suppliers to final customers to increase all organizations' market competitiveness. If a researcher is interested in studying the information used in the supply chain, SCM could be defined as the plan, control and implementation of the information used for the movement of goods and services from the initial suppliers to final customers to increase all organizations' market competitiveness.

In this thesis, SCM means the planning, implementation and control of the flow of products, information and money to improve the efficiency of all organizations in the supply chain. Its purpose is to increase the value added and to improve the cost efficiency by getting the right product, at the right price, in the right quantity, to the right place and at the right time. This demands the quick assignment of resources and accurate synchronization of activities in the supply chain. The more detailed content of SCM is evident from the Supply Chain Operations Reference (SCOR) model (SCC 2005). This model links the process elements, metrics, best practice and features associated with the supply chain. The SCOR model in Figure 2 describes five SCM processes.

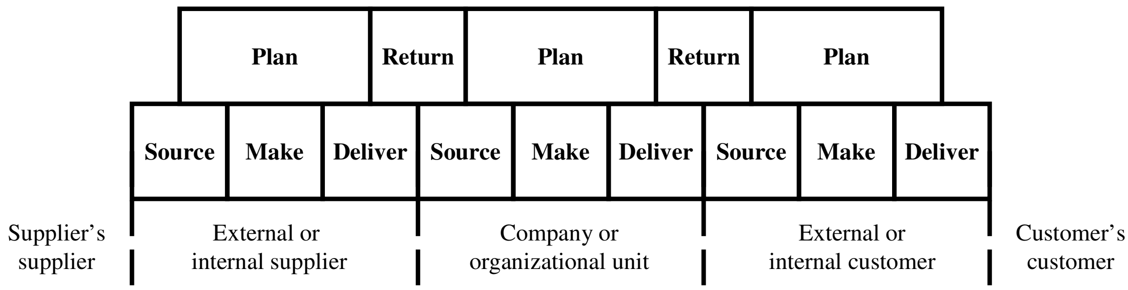

Figure 2: SCM processes

- The *plan* process consists of business functions that balance aggregated demand and supply. For example, this process covers the demand forecasting function to send strategic forecasts to suppliers and the resource management function to receive inventory reports from customers.

- The *source* process contains business functions to procure products that meet the planned or actual demand. For example, this process includes the purchases function to send purchase orders to suppliers.

- The *make* process includes business functions that transform products to a finished state to meet the planned or actual demand. For example, this process can contain the product design function to exchange engineering changes with customers or suppliers. Although product development has not been traditionally associated with SCM, the supply chain includes product development (Lee 2000, Tan et al. 2000).

- The *deliver* process consists of business functions to provide finished products that meet the planned or actual demand. For example, this process contains the sales function to send purchase order responses to customers.

- The *return* process deals with managing a reverse flow of materials and information related to defective, surplus, maintenance, repair or operating products.

Why is SCM important? Jansson et al. (2001) emphasize three reasons:

- *Internationalized companies*: Globalization has led to a situation in which companies, even small and medium-sized enterprises (SME), have subsidiary companies in different countries. Since operations often take place over a geographically wide area, there is a need to economize production and distribution.

- *Complex products*: Products have become complex and a single company alone does not have the necessary resources to realize them. Since the development of resources from scratch may take a lot of time and effort, the best choice may be to utilize the existing resources of other companies. In addition, although a product is not complex, it may have to be customized.

- *Changing markets*: Rapid technological development has resulted in shortening product life cycles. Since profitable opportunities come and go quickly, the market is saturated quickly and new products have to be brought into the market frequently. Therefore, the needs and abilities of different business partners have to be found and matched quickly.

SCM has the potential to have a considerable effect on efficiency. In the worst case, its failure leads to a redistribution of costs and revenues that creates no new value added. In the best case, SCM reduces the response time, i.e. the time when the customer places an order and receives an ordered product, the inventory level and the lead time, i.e. the sum of the working time to convert semi-finished products into finished products and the waiting time at the buffers (Jansson et al. 2001). SCM can also improve capacity utilization. A short response time increases customer satisfaction, which improves competitiveness. A low inventory level reduces the working capital costs and the risk of obsolescence, which improves profitability. Although competitiveness and profitability are not mutually exclusive, a higher inventory level can enable a shorter response time, whereas a longer response time can support a lower inventory level. A short lead time opens up a way to improve both competitiveness and profitability but it requires efficient capacity utilization. On one hand, if overutilization of capacity is possible, it can strengthen competitiveness in the short term. However, overutilization wears out capacity quickly, which weakens competitiveness in the long run. On the other hand, underutilization of capacity erodes profitability because idle capacity generates costs but no revenues. Although these costs are balanced against the revenues, adjustment of capacity may take time and be costly. To improve capacity utilization, the company should be capable of selling its own capacity to other companies when possible and of buying capacity from other companies when needed. This kind of "capacity sharing" supports a short lead time, which in turn enables a low inventory level and a short response time.

2.1.2 Supply chain integration

The term integration has many different definitions in information systems and SCM. Goodhue et al. (1992) conclude that data integration means the standardization of data through the use of common data definitions and structures as well as rules for updating data values. Data integration ensures that data have the same meaning and use across time and users, making the data in different systems consistent. Hasselbring (2000) studies information systems integration in three layers. In the interorganizational processes layer, business process re-engineering aims at continuously improving business processes that cut through the traditional organization structures. In the enterprise application integration (EAI) layer, standardization of message formats and content plays an important role because applications need to understand the data provided by other applications. The concrete syntax and the semantics of standardized messages must be defined for interoperability between applications. In the middleware integration layer, the techniques for building componentized information systems are employed. The borderline between middleware integration and EAI is not always precise. Middleware integration addresses the syntactic level, whereas EAI also addresses the semantic level. Goldfarb and Prescod (2002) present four approaches to integration. In traditional commerce, each customer and supplier may be automated internally. These customers and suppliers connect their systems by manual processes, such as mail, fax and phone calls. Through a web storefront, the customers can view a supplier's catalog of goods and services and place orders directly into a supplier's system. Nothing is necessarily automated on the customer's side. With an e-commerce portal, the customers go to the portal to view the supplier's catalogs and place orders. Suppliers also go to the same portal to view and respond to the orders. In integrated e-commerce, the systems of different companies exchange information directly, which eliminates manual processes. Gulledge (2006) expresses that EAI is the sharing of data and business process logic between multiple systems using a form of middleware. The middleware moves information in and out of multiple systems using pre-engineered connectors. Respectively, B2B integration is the sharing of data but not business process logic through agreed implementation conventions. B2B integration is used to pass information to customers and suppliers.

Trent and Monczka (1998) suggest that there are two interrelated forms of integration in the supply chain. The first type of integration involves the forward coordination of the physical flow from suppliers to customers and the second type of integration the backward coordination of the information flow from customers to suppliers. The forward coordination can be realized by just-in-time management and mass customization, whereas the backward coordination is based on the utilization of ICTs, such as electronic exchange of data. Naylor et al. (1999) state that supply chain integration aims to remove boundaries between organizations by simplifying, streamlining and optimizing the information and physical flows to reduce waste, including time. According to Lee (2000), supply chain integration has three key dimensions that are information integration, coordination and organizational linkage. Information integration refers to the sharing of information and knowledge among the supply chain members. Information integration is the foundation for broader supply chain integration because few gains can be made in overall supply chain integration without information integration. Coordination refers to the redeployment of decision rights, work and resources to the best-positioned supply chain member. In addition, supply chain partners need to define and maintain their channels of communication, specify and monitor performance measures and develop mechanisms, assuring that the associated risks and gains of integration efforts are equitably shared. Frohlich and Westbrook (2002) conclude that demand integration refers to common practices with the customers, such as demand information and inventory visibility, and supply integration to common practices with the suppliers.

In this thesis, supply chain integration is about information sharing between business partners. This information sharing takes the form of exchanging business documents in business processes when these business partners are different companies or different organizational units within the same company. Supply chain integration can be categorized in the following way:

- In manual business interactions, information sharing takes place by meetings, mail, phone calls, faxes or e-mails. Therefore, human intervention is necessary.

- In *semi-automated* business interactions, information systems perform information sharing at one end. At the other end, human intervention is necessary (e.g. by a web browser).

- In *fully automated* business interactions, information sharing happens directly between information systems (e.g. through integration systems). No or minimal human intervention is needed.

Automated business interactions require that the business partners' information systems are interoperable. To achieve this, it is often necessary that the business partner integrates its applications from different software vendors and in-house systems with packaged applications.

Why is supply chain integration important? Since companies and their organizational units have private information often not shared with business partners, asymmetric information is inherent in supply chains. The bullwhip effect is perhaps the most important problem encountered in the supply chain. It happens when the information about the final customers' demand for any product becomes increasingly distorted as it moves toward the initial suppliers in the supply chain (Lee et al. 1997). These distortions cause inaccurate demand forecasts, inefficient resource management and, therefore, high costs and long delays. Reducing the bullwhip effect requires supply chain integration. Moreover, extensive supply chain integration is required to efficiently handle the increased degree of complexity and uncertainty. In all, supply chain integration is a fundamental part of SCM because decision-making is difficult without the relevant information. A short response time requires timely and accurate information sharing with customers, a low inventory level with suppliers and a short lead time and efficient capacity utilization with all business partners. Therefore, supply chain integration is a necessary rather than a sufficient requirement for efficient SCM.

2.2 Data formats and e-business frameworks

2.2.1 ASC X12, EDIFACT and XML formats

In 1968, Transportation Data Coordinating Committee (TDCC) was formed to standardize the electronic exchange of data for all the transportation industries in the US. In 1979, ANSI continued this work and started to develop ASC X12. The first version of ASC X12 was released in 1982. Based on the recommendations of a joint European-North American committee, UNECE engaged the development of EDIFACT in 1986. International Organization for Standardization (ISO) approved EDIFACT as an international standard in 1987. In 1992, ANSI announced that the development of ASC X12 would be abolished by 1997. However, many companies in North America that had invested in ASC X12 saw no benefit in switching over to EDIFACT. It became clear that the development of both ASC X12 and EDIFACT will continue for an unforeseeable future. Data in the ASC X12 or EDIFACT format are represented as EDI messages that are formed of segments. Figure 4 represents the ASC X12 standards version 4 and the EDIFACT syntax version 4 in Extended Backus-Naur Form (EBNF), which is a formal notation to describe the syntax of languages (Aho et al. 1986).

```
Interchange ::= InterchangeHeader (Group+ | Message+) InterchangeTrailer
Group ::= GroupHeader Message+ GroupTrailer
Message ::= MessageHeader Segment+ MessageTrailer
Segment ::= Code (ESeparator Repetition)+ Terminator
Repetition ::= Composite (RSeperator Composite)*
Composite ::= Simple (CSeparator Simple)*
Simple ::= Data?
```

Figure 3: The basic grammar of the ASC X12 and EDIFACT formats

The EDI formats can be illustrated with the following example concerning a purchase order document. According to this purchase order, a delivery is wanted to be shipped to the end user "SoberIT" in the organization "TKK", which has the street address "Tekniikantie 14" and the postal code "02150" in the city of "Espoo" in the country of Finland. Figure 4 represents this information in the ASC X12 format and Figure 5 in the

EDIFACT format. ASC X12 specifies the segment codes “N1”, “N2” etc…, EDIFACT the segment code “NAD” and both e-business frameworks the element values “ST” and “FI”.

```
N1*ST*TKK~
N2*SoberIT~
N3*Tekniikantie 14~
N4*Espoo**02150*FI~
```

Figure 4: An excerpt from an ASC X12 850 Purchase Order document

```
NAD+ST++TKK+SoberIT+Tekniikantie 14+Espoo++02150+FI'
```

Figure 5: An excerpt from an EDIFACT ORDERS document

In 1969, IBM started to develop Generalized Markup Language (GML) to be used to manage industrial documents. ANSI became interested in GML and started the development of SGML for electronic document management. ISO approved SGML as an international standard in 1986. HTML, which is perhaps the most important use of SGML, was developed for web publishing at CERN. In 1995, Internet Engineering Task Force (IETF) standardized HTML. In 1996, W3C established a committee to develop a standard that would not be as complex as SGML and as fixed as HTML. As a result of this work, W3C published XML in 1998. Data in the XML format are represented as an XML document that is formed of elements. Figure 6 represents the XML recommendation 1.0 in EBNF.

```
Document ::= Declaration Element Miscellaneous*
Element ::= EmptyTag | StartTag Content EndTag
EmptyTag ::= “<” Name (Space Attribute)* Space? “/>”
StartTag ::= “<” Name (Space Attribute)* Space? “>”
Content ::= CData? (Element CData?)*
EndTag ::= “</” Name Space? “>”
Attribute ::= Name Space? “=” Space? Value
Value ::= “'” VData? “'” | “"” VData? “"”
```

Figure 6: The basic grammar of the XML format

Figure 7 represents a purchase order example in the XML format. RosettaNet Partner Interface Process (PIP) specifies the element names “shipTo”, “BusinessDescription” etc…, the element contents “End User” and “FI”, the attribute name “xml:lang” and the attribute value “FI”.

There is a large number of XML technologies available (W3C 2005). Considering supply chain integration, three basic XML technologies are interesting. Document Type Definition (DTD), which originates from SGML, specifies the structure of the XML documents. XML Schema Definition (XSD), an XML-based language, offers more capabilities of specifying the structure of the XML documents. Extensible Stylesheet Language Transformations (XSLT) is an XML language for transforming XML documents into other XML documents.

```
<shipTo>
  <BusinessDescription>
    <businessName>
      <FreeFormText xml:lang="FI">TKK</FreeFormText>
    </businessName>
    <PartnerBusinessIdentification>
      <ProprietaryDomainIdentifier>SoberIT</ProprietaryDomainIdentifier>
      <ProprietaryIdentifierAuthority>TKK</ProprietaryIdentifierAuthority>
    <PartnerBusinessIdentification>
  </BusinessDescription>
  <GlobalPartnerClassificationCode>End User</GlobalPartnerClassificationCode>
  <PhysicalLocation>
    <PhysicalAddress>
      <addressLine1>
        <FreeFormText xml:lang="FI">Tekniikantie 14</FreeFormText>
      </addressLine1>
      <cityName>
        <FreeFormText xml:lang="FI">Espoo</FreeFormText>
      </cityName>
      <GlobalCountryCode>FI</GlobalCountryCode>
      <NationalPostalCode>02150</NationalPostalCode>
    </PhysicalAddress>
  </PhysicalLocation>
</shipTo>
```

Figure 7: An excerpt from a RosettaNet PIP 3A4 Purchase Order Request document

2.2.2 Basic properties of e-business frameworks

As the late 1990s saw the emergence of standards for e-business, there are a number of papers discussing such standards with different terms. Shim et al. (2000) call these standards B2B frameworks, Li (2000) industrial standards for e-commerce, Zhao and Sandahl (2000) frameworks for Internet commerce, Gosain et al. (2003) B2B interface specifications and Medjahed et al. (2003) B2B interaction standards. The term XML/EDI is also used (e.g. Hsieh and Lin 2004).

What are the standards for e-business? This is not a simple question because the promoters of the standards for e-business characterize their standards in different ways. xCBL (Commerce One 2004) "is a set of XML building blocks and a document framework that allows the creation of robust, reusable, XML documents for e-commerce". RosettaNet (2004) is "a robust nonproprietary solution, encompassing data dictionaries, implementation framework, and XML-based business message schemas and process specifications, for e-business standardization". Electronic Business XML (ebXML) (OASIS 2004b) "is a modular suite of specifications that enables enterprises of any size and in any geographical location to conduct business over the Internet". Business Process Execution Language (BPEL) (OASIS 2004a) focuses on "specifying the common concepts for a business process execution language".

In order to operate across organizational boundaries, business partners must have a shared understanding of their ways of doing business. To automate business interactions, their information systems must be capable of processing and communicating data. Business partners involved have to know what information should be shared, when and how. Interoperability of business documents, business processes and messaging concern the questions and answers necessary in information sharing. An e-business framework is a standard for information sharing within and between companies. It answers or provides the means to answer the questions of what, when or how. E-business frameworks cover the business and technical aspects of business documents, business processes and messaging. They often combine other standards, specifications and classifications. The interoperability issues outline the basic properties of the e-business framework:

- *Business document issues* relate to what information should be shared between the business partners. In business document issues, the e-business framework defines or provides means to define the structures and elements of the business documents as well as the meanings for terms used in these documents. For example, if a customer sends a purchase order to a supplier, this business document includes the customer's and the supplier's name and address, the product name and ordered quantity.

- *Business process issues* relate to when information should be shared between the business partners. In business process issues, the e-business framework defines or provides means to define the business partners' roles, in which order to exchange the business documents as interactions or to handle information of the business documents as actions in the business processes. For example, if a supplier has received a purchase order from a customer, the supplier must send a purchase order response to the customer in the order management process. There are different levels in defining the business processes. At the rough level, the focus is directed towards roles and interactions, whereas actions are also taken into account at the detailed level.

- *Messaging issues* relate to how information should be shared between the business partners. In messaging issues, the e-business framework defines how business documents are exchanged. Messaging issues specify the envelope to package a business document in the message as well as the structure and elements used in a header of the message. The e-business framework also defines the transport, packing and security standards to be used. In addition, messaging issues include the basic requirements of exception handling. For example, if a customer and a supplier exchange purchase orders and purchase order responses, they use Hypertext Transfer Protocol (HTTP) as the transport standard, Multipurpose Internet Mail Extensions (MIME) as the packing standard and Security Multiparts for MIME (S/MIME) as the security standard in the exchange of these business documents in the order management process.

The e-business framework always has a particular target. The *cross-industry* e-business framework aims to cover all industries, whereas the *industry-specific* e-business framework focuses on one or a few industries. The *cross-industry-document* e-business framework uses a data format in business documents, whereas the *cross-industry-process* e-business framework utilizes a data format as a means to specifying *public* business processes, i.e. business processes between companies, or *private* business processes, i.e. business processes within a company. In comparison, the industry-specific e-business framework uses a data format in the business documents but it does not provide new means to specify the business processes.

2.2.3 Data formats in e-business frameworks

Since many e-business frameworks utilize the ASC X12, EDIFACT or XML format, this raises the question of the division of labor between the data formats and e-business frameworks. The syntactic and semantic interpretations (Russell and Norvig 1995) are necessary in understanding the business documents. The syntactic interpretation is divided into lexical and syntactic analyses and the semantic interpretation into semantic and pragmatic analyses:

1. *Lexical analysis* scans the characters of the business document and produces tokens according to the lexicon that defines the acceptable combinations of characters in the language. Since the EDI formats do not define all segment codes and element values, an EDI-based e-business framework is necessary. The XML format does not define element names, attribute names, element contents and attribute values. An XML-based e-business framework utilizes DTD or XSD to specify the elements and attributes.

2. *Syntactic analysis* obtains the tokens and generates a tree of symbols according to the grammar that defines the structure of the language. If the meanings for the symbols are independent of this structure, a data format is enough. Otherwise, the EDI-based e-business framework needs to define the number and position of each segment and element in the EDI message and the XML-based e-business framework uses DTD or XSD to specify the number and position of each element and attribute in the XML document.

3. *Semantic analysis* recognizes what the symbols denote and associates the alternative meanings to the symbols in the tree. Data formats alone cannot help if the symbol is ambiguous or non-descriptive. The e-business framework defines the relevant meanings for each symbol.

4. *Pragmatic analysis* interprets the symbols in the prevailing context. For each symbol, the most suitable meaning is chosen from the alternative ones, taking into account other symbols and their alternative meanings. Since data formats are context-free languages, their assistance is incomplete in this choice. The e-business framework should guide the choice of the meaning. However, if the knowledge related to this choice cannot be explicated, it is difficult to record this knowledge in the e-business framework.

Comparing EDI-based and XML-based e-business frameworks, ASC X12 and EDIFACT comprise a starting point for many other EDI-based e-business frameworks. ASC X12 and EDIFACT offer a number of generalized message types, from which each SDO can tailor subsets suitable for its specific requirements only by replacing the conditional segments and elements with new appropriate qualifiers. An important characteristic is that each subset must keep the same overall data structure for the message type to which the subset belongs. In comparison, some XML-based e-business frameworks use the XML format in business processes and messaging. The role of the XML format is not as self-evident in business processes as it is in business documents. The cross-industry-document and industry-specific e-business frameworks can define business processes using diagrams and verbal descriptions. The cross-industry-process e-business frameworks use the XML format to represent a business process in a machine-executable format. With regard to messaging issues, the e-business framework may use the XML format in the headers, which contain data to route the message and to process its content and attachments. The content is always a business document. Other uses of the XML format depends on standards referred to by the e-business framework.

In summary, the data format is necessary in the syntactic interpretation but insufficient in the semantic interpretation. The e-business framework limits the syntax but extends the semantics of the data format in the business context.

2.3 Related literature

2.3.1 Standards and standardization

Although standardization is not an unusual subject in the literature, only few papers seem to deal with ICT standardization at the general level (Lyytinen and King 2006). One conclusion is that the user's role has been less important in standardization than the vendor's role. Jakobs et al. (1998) point out that companies with different cultural backgrounds are likely to have very heterogeneous needs and requirements, as they represent their own interests instead of those of "general" users. Jakobs (2002) suggests that standardization takes place in markets and committees. Moreover, users appear to be adopting technology assuming that it represents the "real" standard because it is the most widely adopted technology. Many users are less motivated than the vendors to go to any length to influence standardization because tailor-made solutions hold the promise of faster solutions to the user's current problems.

The economics of standards emphasizes network externalities and path dependences. *Network externality* refers to a change in the value that a user derives from technology when the number of other users of the same kind of technology changes (Katz and Shapiro 1985). Direct network externalities are generated through the physical effect of the number of users of the same technology. For example, the benefit that an agent derives from purchasing a telephone depends on the number of other agents that have the telephone. Indirect network externalities occur when the number of users of a particular technology has an effect on the availability of complementary technologies. For example, an agent purchasing a computer will be concerned about the number of other agents purchasing a similar computer because the benefit of the computer depends on the number of computer programs that will be affected by the number of these computers. Liebowitz and Margolis (1994) argue that network externalities are often effects rather than externalities. Many direct network externalities can be internalized through ownership. Indirect network externalities generally do not impose welfare losses that should be internalized. *Path dependence* means that history matters because one equilibrium is chosen from multiple equilibria by interacting with economic forces and random events (Arthur 1989). When technologies compete for users, insignificant events may give one technology an advantage by a change so that this technology improves more than other technologies and induces a larger number of users. According to Liebowitz and Margolis (1995), knowledge of initial conditions does not tell much about the eventual path over time. A chosen path is not necessarily uniquely optimal, although a shift from the current path to the others' optimal path is costly. A path can also be optimal when a choice was made but not necessarily optimal in retrospect. Finally, inefficiencies are often remediable.

Farrell and Saloner (1985) point out that the adoption of a standard is always efficient when the users are certain about other users' benefits from its adoption, although they have different preferences for the standard. However, an inferior standard may prevail or be chosen if the users are uncertain about other users' benefits. According to Katz and Shapiro (1986), there is a bias toward non-standardization of non-proprietary technologies when standardization would be optimal. If standardization occurs, the non-proprietary technology that initially is superior has an advantage, although it is not the optimal one. For non-proprietary and proprietary technologies, there is still a bias toward non-standardization. If standardization occurs, the proprietary technology has an advantage. Standardization of the proprietary technology may occur when non-standardization would be optimal. If there are proprietary technologies, standardization always occurs. The proprietary technology that later is superior has an advantage, although it is not the optimal one. Farrell and Saloner (1986) conclude that markets are faster but committees cause fewer errors in standardization. Although the value of speed is taken into account, committees are still more efficient than markets. However, hybrids of committees and markets are even more efficient than committees. Shapiro and Varian (1999) suggest that positive feedback works for large networks and against small networks, expectation management is crucial to build positive feedback and formal settings are now being used to develop more standards than ever before. In addition, introducing new products faces one trade-off between performance and compatibility and another between openness and control, although it is important to retain limited control over the technology even when establishing an open standard.

The economics of standards uses a small number of empirical examples to motivate the problems examined at the theoretical level. In the most well-known example, David (1985) argues that the QWERTY keyboard layout, which was patented in 1868 by Christopher L. Sholes and became the prevailing keyboard layout early, is inferior, given current needs. This keyboard was designed to minimize key sticking in typewriters, whereas computer keyboards cannot stick. In addition to QWERTY, a superior alternative, Dvorak Simplified Keyboard (DSK) layout, exists and its benefits outweigh the switching costs. This implies that there is a lock-in to an inferior alternative. Liebowitz and Margolis (1990) argue that the superiority of DSK layout has never been firmly established. They note that classic tests of DSK layout are inconclusive and possibly influenced by August Dvorak who patented this keyboard layout in 1932.

In all, standardization may fail in many different ways. Although a superior standard exists, an inferior standard may be chosen. A standard may be adopted too quickly or too slowly. There may also be no standard or too many standards. This is a paradox because if too many "nominal" standards coexist, no "real" standard exists.

2.3.2 EDI-based supply chain integration

The literature provides a very large number of papers on EDI-based supply chain integration (Elgarah et al. 2005). Table 1 summarizes statistical EDI studies.

Table 1: Statistical EDI studies

Reference	Findings
Carter and Fredendall (1990)	The greatest cost savings resulted from paper-work costs, lead-time reductions, data-input errors and inventory reductions, not personnel reductions or new hire avoidance. After EDI implementation, a purchasing professional spent significantly less time performing routine clerical activities and more time performing professional and managerial activities.
Premkumar et al. (1994)	Relative advantage, costs and technical compatibility are the major predictors of EDI adoption. Relative advantage and duration are important predictors of internal EDI diffusion, whereas technical compatibility and duration are important predictors of external EDI diffusion. Finally, technical and organization compatibility and costs are the major predictors of EDI implementation success.
Premkumar and Ramamurthy (1995)	Competitive pressure and exercised power as well as internal need and top management support are important variables to differentiate companies with proactive mode from companies with reactive mode. Proactive companies have a greater degree of adoption, more external connectivity with trading partners and better EDI integration in their applications.
Ramamurthy and Premkumar (1995)	The company's EDI compatibility with its technology and work practices as well as the advantages obtained through being an early adopter are key determinants of internal and external EDI diffusion. Scope for EDI within the company's task environment is also a key determinant of internal EDI diffusion.
Mackay and Rosier (1996)	The number of employees and annual turnover has an important direct effect on EDI benefits.
Bergeron and Raymond (1997)	The organizational support and control procedures maintain and the implementation process and imposition lose their importance with time. Imposing EDI is associated with lower EDI advantages in the short run but it does not have such an effect in the long run. The level of EDI advantages increases with time, especially information quality.
Premkumar et al. (1997)	The firm size, competitive pressure, customer support and top management support affect positively EDI adoption.
Prosser and Nickl (1997)	Compared to company-specific EDI, generic EDI reduces asset-specificity and makes additional business partners available but its use alone does not reduce mutual dependence.
Ramamurthy et al. (1999)	External EDI integration is important to both operational and market performance and internal EDI integration to operational performance.
Chwelos et al. (2001)	The competitive advantage and enacted trading partner power contribute positively to the intent to adopt EDI. Industry pressure is not influential in motivating companies to adopt EDI.
Iskander et al. (2001)	The higher the frequency of transactions and the higher the percentage of sales to a customer the more likely a supplier is to adopt EDI. Pressure from the customers seems to be the most significant reason for the suppliers to adopt EDI. The factors affecting EDI adoption are different from the factors affecting EDI success.

Kuan and Chau (2001)	EDI adopters perceive direct benefits from EDI to be higher than non-EDI adopters. However, they perceive indirect benefits in the same way. EDI adopters also perceive lower financial costs, higher technical competence, higher government pressure and lower industry pressure than non-EDI adopters.
Carr and Smeltzer (2002)	The increased use of EDI connections may result in a decrease in the frequency of face-to-face communication between the customers and suppliers. Other direct computer-to-computer connections can cause face-to-face communication to be more efficient if minor issues are resolved through electronic communication before face-to-face communication. In addition, other direct computer-to-computer connections are to some extent related to the richness of information shared between the customers and suppliers.
Hill and Scudder (2002)	Companies view EDI as a tool for improving efficiencies rather than as a tool for facilitating supply chain integration. Companies also tend to be much more accommodating of the desires of their customers than of their suppliers.
Sriram et al. (2002)	Larger companies in terms of sales and customer-initiated EDI users recognize both strategic and operational benefits arising from EDI in greater proportions than smaller and voluntary EDI users. EDI users from the manufacturing and services industries recognize these strategic and operational benefits in the same way.
Kaefer and Bendoly (2004)	There is a strong support for the view that a higher compatibility with non-EDI technologies among business partners produces greater transactional efficiencies but only a weak support for EDI technologies.
Soliman and Janz (2004)	EDI over the Internet and EDI over the VANs are similar in terms of pressure from business partners and competition. There are differences in terms of costs and complexity. Taking these factors into consideration, companies favor EDI over the Internet.

Of statistical EDI studies, seven studies deserve special attention. Venkatraman and Zaheer (1990) have studied the effects of EDI on performance of an insurance carrier with respect to about 70 EDI agents and 70 matched non-EDI agents. The EDI agents reported increases in total written premiums, commissions and number of polices in force after EDI implementation. However, they had significantly larger increases only in new business policies than the non-EDI agents. Mukhopadhyay and Kekre (2002) have analyzed strategic and operational benefits of a tool supplier from EDI. For part of strategic benefits, the supplier had the volume of sales to 159 EDI customers that was not significantly higher than the volume of sales to 159 matched non-EDI customers. However, the supplier had additional sales when the customer had initiated EDI, implemented enhanced EDI or used EDI with the supplier for more than three and a half years. With regard to operational benefits, orders of 119 EDI customers and 119 matched non-EDI customers were analyzed. Invoices with EDI reduced the probability of delayed customer payments and fully integrated EDI reduced the probability of credit orders.

Riggins and Mukhopadhyay (1994) have studied two customer-initiated EDI systems. The first case was based on 2076 requests for purchase that were collected from one division of the electronics company's procurement department. Automated vending feature of the customer's EDI system greatly reduced the time required internally to generate a request for purchase. However, this feature had insignificant effects on the supplier's response time. The second case covered 146 assembly suppliers of an automotive manufacturer. Those suppliers who had integrated their internal systems to EDI had fewer errors in advance shipping notices. Srinivasan et al. (1994) have analyzed shipments from 193 suppliers to Chrysler. Those suppliers, who shared just-in-time schedules, had fully integrated EDI or used EDI with a higher percentage of customers, had a lower level of shipment discrepancy. Mukhopadhyay et al. (1995) have studied EDI at Chrysler. Based on the annual performance of nine assembly plants over a ten-year period, EDI improved inventory turnover (ITO) and reduced obsolescence costs and premium freights. Including additional savings in information handling costs, the total benefits of EDI per vehicle amounted to 100.89 USD. This yielded annual savings of 220 million USD for Chrysler.

Clark and Stoddard (1996) have analyzed the performance of 26 grocery retailers over a five-year period. EDI with manufacturers did not result in a significant increase in ITO but grocery channel replenishment ordering increased ITO significantly. Lee et al. (1999) have investigated the performance of 31 grocery retailers over a four-year period. EDI with Campbell for continuous replenishment process increased ITO and reduced stockouts.

In summary, the benefits of EDI have been recognized for a long time (Banerjee and Golhar 1994, Emmelhainz 1990, Scala and McGrath 1993). Although EDI does not necessarily increase sales (Mukhopadhyay and Kekre 2002, Venkatraman and Zaheer 1990), its use can reduce operating costs (Mukhopadhyay et al. 1995). The use of EDI can also speed up and reduce errors in business interactions (Mukhopadhyay and Kekre 2002, Riggins and Mukhopadhyay 1994, Srinivasan et al. 1994). Its direct benefits, such as avoiding repetitive administrative procedures, are often perceived larger than indirect benefits, such as improving business relationships (Jiménez-Martínez and Polo-Redondo 2004, Kuan and Chau 2001).

A company may use EDI with a small fraction of its business partners but other methods with the remaining business partners (Von Westarp et al. 1999). It is not unusual that a company uses EDI to exchange purchase orders, purchase order responses and invoices but other methods to perform other business interactions (Kärkkäinen et al. 2001). EDI adoption and diffusion are often gradual (Premkumar et al. 1994). A company starts to use EDI with one of its business partners and for only one type of the various business documents used in business interactions with this business partner. Then, the company can increase the number of its business partners or extend the use of EDI to other types of business documents.

The use of EDI has concentrated on large enterprises, whereas SMEs have hesitated with its use (Banerjee and Golhar 1994, Hill and Scudder 2002, Premkumar et al. 1997). If a SME uses EDI, this happens due to pressure from competitors or business partners (Chwelos et al. 2001, Iacovou et al. 1995, Premkumar et al. 1997, Soliman and Janz 2004). SMEs tend to lack the needed high organizational readiness and perceived benefits for EDI. SMEs are also reluctant to integrate EDI into their operations because it is too costly. SMEs do not adopt EDI because the investment is not in EDI alone but also in an information system that supports its use, the customers do not use EDI or the volume of business interactions is too small to justify the investment in EDI (Stefansson 2002). As Massetti and Zmud (1996) note, the use of EDI should not only be seen in terms of volume, i.e. the extent to which a company exchanges business documents through EDI connections, and breadth, i.e. the extent to which the company has established EDI connections with its business partners. Diversity, i.e. the number of distinct types of business documents the company handles through EDI connections, and depth, i.e. the nature of EDI connections with its business partners, also matter.

2.3.3 XML-based e-business frameworks

Two papers deal with the role of XML and other standards in supply chain integration. According to Hasselbring and Weigand (2001), the standardization for the exchange and processing of documents can be at the lexical level of character sets, at the syntactic level of document structures and at a deeper semantic level of vocabulary and integrity constraints. Medjahed et al. (2003) show that the B2B interaction standards deal with communication, content and business process layers. These layers provide protocols for exchanging messages between business partners, languages and models to describe and organize information, and are concerned with conversational interactions between business partners.

There also exist papers studying XML-based e-business frameworks (Chari and Seshadri 2004, Li 2000, Medjahed et al. 2003, Nelson et al. 2005, Shim et al. 2000, Zhao and Sandahl 2000). BizTalk Framework and RosettaNet are included in five of these papers, eCo, its business document specification, Common Business Library (CBL), or xCBL and cXML (Commerce XML) (Ariba 2004) in four papers and ebXML and OAGIS (Open Applications Group Integration Specification) (OAG 2004) in three papers. Table 2 summarizes these papers.

Table 2: Studies on XML-based e-business frameworks

Reference	XML-based e-business frameworks	Compared properties
Li (2000)	Six	Number of DTDs, number of attributes and elements in DTDs, size of DTD files
Shim et al. (2000)	Four	Industry target, security, communication protocol, service discovery, repositories, message format, query mechanism, scalability, ontology
Zhao and Sandahl (2000)	Six	
Medjahed et al. (2003)	Five	Communication layer, content layer, business process layer, type of coupling, autonomy, heterogeneity, external manageability, adaptability, security, scalability
Chari and Seshadri (2004)	Seven	Industry domain specificity (domain independent, domain dependent), applications architecture (presentation logic, business logic, data logic), integration level (transport, data format, process)
Nelson et al. (2005)	Nine industry-specific	Choreography and modularity (number and examples of high-level processes, number and examples of specification sets), standardize and document (content examples of typical specification sets)

Except for Nelson et al. (2005), these papers stress the properties of XML-based e-business frameworks, not their standardization. Li (2000) classifies SDOs as a basis of the selection of e-business frameworks but standardization is not reflected in the analysis. Chari and Seshadri (2004) show that most XML-based e-business frameworks are consortia-based standards and only a few of them are company-based specifications.

Nelson et al. (2005) provide a comparative analysis of nine SDOs, including the standardization of CIDX (Chemical Industry Data Exchange) (2004), papiNet (2004), PIDX (Petroleum Industry Data Exchange) (API 2004) and RosettaNet, with respect to decision-making, availability, membership fee, industry participation and certification. The key differences between these SDOs are related to the partnership structure. Non-profit status, free provision of standards, voluntary participation, consensus-driven decision-making, management adhering to by-laws are common in SDOs. There are also commonalities associated with the membership fees.

Drawing on the socio-technological perspective, Choi et al. (2004) attempt to gain a deeper understanding of standardization of ebXML by using a case study methodology. The standardization of ebXML was observed through e-mail discussions, minutes of teleconferencing, face-to-face meetings and other supplementary materials. Choi et al. (2004) suggest that non-proprietary standardization helps collaborators create a more comprehensive standard and promote more the convergence of technologies than proprietary standardization. Interoperability and backward compatibility are critical factors in the creation of infrastructure-oriented standards, whereas feasibility is a critical factor in the creation of business-process-oriented standards. In addition, user participation is a moderating factor in non-proprietary standardization for achieving a comprehensive and converged standard and appears to be more effective in creating infrastructure-oriented standards than in business-process-oriented standards.

Aggarwal et al. (2006) use an event study methodology to analyze the market value of non-proprietary standardization in 148 XML-based standardization initiatives between 1999 and 2003. The results suggest that financial markets respond positively to announcements of XML-based proprietary standardization but not to announcements of XML-based non-proprietary standardization. Proprietary standardization results in an average 2% increase in a company's stock price, whereas non-proprietary standardization reduces the stock price slightly. Moreover, financial markets do not develop a preference for non-proprietary standardization over time.

2.3.4 XML-based supply chain integration

There seems to be little experience from XML-based supply chain integration after excluding the software vendors' success stories. The literature provides few scientific papers and research reports. The first ten studies focus on the integration system prototypes and the remaining studies concentrate on the operative integration systems.

Fürst and Schmidt (2001) developed a prototype called Data-Extractor for BMW Motors Steyr in Austria to enable the data for controlling the parts delivery to be available for all customers, suppliers and carriers of this factory. The prototype was implemented with Java servlet running on a web server. It handles the requests from the different information systems and users working with a web browser. The prototype was designed to support warnings of problems in parts deliveries, reports of the actual status of a parts transport from the carriers, report of the actual parts stock at BMW and the suppliers, report of the incoming of a delivery, and sending of the actual delivery data to

BMW. The prototype was tested with simulation data but not connected to the information systems at BMW, the carriers or suppliers.

Lu et al. (2001) implemented a prototype server for Taiwan's flower distribution channels using Microsoft Internet Information Server, Xerces and Xalan. The prototype was developed because many farmer associations, retailers, carriers and wholesalers cannot afford to maintain this kind of a server and there was no EDI-based e-business framework for the Taiwanese agricultural industry. The idea was that an outside organization could be in charge of running this server. First, the farmer associations upload bills of lading to the server daily. Next, this server notifies wholesalers by e-mail, the wholesalers download the bills, process them and upload the invoices. Then, the server notifies the farmer associations by e-mail and these associations download the invoices. Lu et al. (2001) do not report the experiences from the prototype sever in real cases.

Sundaram and Shim (2001) present a prototype for RosettaNet that allows the customers to order by a web browser. The client tier of the prototype provides a web form using HTML and JavaScript. Its business logic tier processes the request from the client tier and sends the response. This tier is implemented by Java servlet that communicates with the sales and fulfillment application by HTTP. It encapsulates the functionality required to perform the PIPs and to transform data to XML documents. The business logic tier uses the database tier of the prototype for storing and retrieving information. The database contains information obtained from RosettaNet Technical Dictionary (RNTD). The sales application displays the catalog to browse different products and to query information for these products and allows submission of a purchase order as an XML document to the fulfillment application. The fulfillment application processes the XML document, sends the order number to the customer and maintains a detailed profile of each customer and the status of the orders. The administrator of this application can update the order status to either being approved or shipped.

Buxmann et al. (2002) developed a prototype called SIMPLEX that uses XML to describe and structure business documents, supports the execution of information exchange, the transformations between different XML vocabularies and the integration into in-house systems. The prototype was implemented with Apache web server and integrated to Tamino XML database. It also uses the XML parser Xerces and the XSLT processor Xalan. The prototype is capable of handling Invoice, CatalogueQuery, DeliveryConfirm, Delivery Schedule, Forecast, InventoryQuery, MonitoringTransaction, OrderConfirm, Reclamation, SalesOrder, and PurchaseOrder documents. The supported e-business frameworks include xCBL and OAGIS. Although Buxmann et al. (2002) did not test the prototype in a real case, they claim that business partners can use XML as a common language, building on it different business vocabularies and XSLT for translations between these vocabularies.

Chan et al. (2002) present a prototype for retail inventory control that was implemented with Java servlets. Based on XML, Inventory Control Markup Language was developed to construct the data models and specify the data exchange format between the prototype and client applications. It defines DTDs for ServiceRequest, ServiceResponse, ResourceAccess, ResourceAccessResult, Buyer, Supplier, Item and PurchaseOrder documents. The prototype provides services for transaction data capture, assortment planning and automated replenishments. The transaction data capture services are aimed at defining and maintaining basic item information, recording and issuing purchase orders to the suppliers, updating information on the received items, adjusting inventories and performing item information lookups, calculating discounts and capturing sales-related information. Chan et al. (2002) report some test results of the computational performance of the prototype.

Dogaz et al. (2002) implemented a prototype of an ebXML infrastructure by exploiting the PIPs and Universal Description, Discovery and Integration (UDDI) registry. The prototype includes tools for specifying business processes based on the PIPs and for storing ebXML document and process descriptions into the UDDI registry. This prototype also provides mechanisms for secure messaging based on ebXML Messaging Services (MSG) that use Simple Object Access Protocol (SOAP) and MIME.

Goutsos and Karacapilidis (2004) report on the development of an XML-based supply chain management system for the Greek textile industry. Using Microsoft BizTalk Server, this system integrated its internal workflow management module, demand-side transactions module and supply-side transactions module with the company's ERP system. The internal workflow management module deals with the processes and the related business documents. The demand-side transactions module is a web-based application, through which customers can put an order. The supply-side transactions module manages the electronic exchange of business documents with the suppliers. XML was chosen because the adoption of EDI implied certain tasks and limitations.

Kotinurmi et al. (2004) designed and implemented a prototype using RosettaNet and Microsoft RosettaNet Accelerator that supports design data management in product development networks. For example, it can automatically deliver and receive the latest version of design documents. Experiences with the implementation and use indicated that RosettaNet is basically feasible for this purpose. However, there were also several problems with the use of RosettaNet. The secure exchange of business documents according to RosettaNet Implementation Framework (RNIF) was easy to implement but large attachments can cause problems. The PIPs were not defined with product development in mind. It was necessary to misuse certain PIPs in order not to lose information. First, PIP Notify of Engineering Change Order (2C5) was used with change request documents and PIP Distribute Product Catalog Information (2A1) for new document delivery. Later, PIP 2A1 was replaced by PIP Distribute Design Engineering Information (2A10). The first PIPs enabled meaningful carrying of only roughly 30% of the internal data model information. PIP 2A10 increased this to 85% but for some of the elements of the internal data model this meant only a close match to the term in RosettaNet Business Dictionary (RNBD). In addition, the use of both DTDs and RosettaNet Message Guidelines (MG) for business document validation was problematic. If the MGs are ignored and only DTDs are used, the business partners involved need to agree each time on how to use certain elements.

Chiu and Chen (2005) present a common message gateway prototype compliant with RosettaNet. This prototype was integrated with information systems for secure message exchange with the business partners. The common message gateway was tested in a local network device manufacturing company with its suppliers in Taiwan to examine its feasibility and efficiency. The tests showed that this common message gateway can help the company achieve efficiency and effectiveness in streamlining information flows and creating seamless integration with its business partners. The benefits gained from XML-based supply chain integration over the Internet seemed to have more significance than those from EDI-based supply chain integration over the VANs because of cost-effectiveness and time savings.

Tikkala et al. (2005) implemented a prototype for the messaging part of RosettaNet using IBM WebSphere Application Server and common open-source tools, such as Apache Axis, Xalan and Xerces. The prototype is a middleware component that provides a RNIF interface outside and a Web Services interface inside the company. It was found that the approach in RosettaNet for specifying business documents, i.e. DTDs with MGs, is not suitable for automatic generation of the component that satisfies minimum business document validation requirements in RNIF. In addition, the available amount of memory constrained the maximum size of the business documents because the prototype needed 6-14 times more memory than the size of the business document. Based on tests, the performance level for messaging begins to be a problem when a load exceeds one exchanged business document per second.

RosettaNet is perhaps the most successful XML-based e-business framework. The number of RosettaNet implementations have been estimated to exceed 10000 connections (Damodaran 2004). There is available a large number of non-academic RosettaNet studies that are summarized in Table 3. Most of these studies deal with quote and order entry (segment 3A) and collaborative forecasting (segment 4A). In quote and order entry, RosettaNet has reduced manual workload and shortened order cycle times. In some studies, these benefits have been small but significant despite the preexistence of EDI (Olson and Williams 2001, RosettaNet 2001, 2002b). In collaborative forecasting, RosettaNet has shortened forecast-to-shipment time and inventory costs.

e-Business W@tch asked European companies in 2003 and 2005 (e-Business W@tch 2004, 2005) whether they exchange standardized data with their customers or suppliers and which data formats they used for this purpose. Some general trends were identified from companies that use computers in business. Firstly, 9% of these companies used EDI-based e-business frameworks in 2003 and 19% in 2005, whereas 8% of them used XML-based e-business frameworks in 2003 and 14% in 2005. Secondly, EDI-based e-business frameworks were popular in the chemicals and chemical products sector in 2003 and in the automotive subsector in 2005. XML-based e-business frameworks appeared to be widely used by companies from the business services sector in 2003 and from the IT services subsector in 2005.

Table 3: Non-academic RosettaNet studies

Reference	PIPs	Benefits
Olson and Williams (2001)	3A4, 3A6, 3B2	Shortened order processing time by 1 day Shortened shipment-to-invoice time by 3 days Annual cost savings 400000 USD
RosettaNet (2001)	3A4	Reduced manual workload by 93-95% Increased ITO by 200% Shortened response time by 75-97%
RosettaNet (2002a)	4A4, 4B2, 4C1	Reduced manual transactions by 80% Contract costs savings by 50% Increased capacity utilization by 30%
RosettaNet (2002b)	3A4, 3A8, 3A9, 3B2, 5D1	Transaction cost savings in orders by 16-37% Increased order throughput by 0-1900% Reduced order cycle time by 0-99%
RosettaNet (2003)	3A4, 3A8, 3B2	Reduced manual workload by 50% 100% error-free process Shortened order throughput time by 96% Increased throughput by 200%
Case A in RosettaNet Japan (2003)	4A3, 4A4	Reduced inventory costs Administrative costs savings by 50-79% Reduced change orders by 52% Shortened delivery lead time by two days Shortened delivery planning from monthly to weekly Shortened the time from planning to shipping by 40% Reduced probability of human error Increased accuracy of forecasts by 5%
Case B in RosettaNet Japan (2003) and Intel (2004)	3A4, 3A7, 3A8, 3B2, 3C3, 3C6	Reduced manual work in orders Time savings in orders 56-67% Time savings in advance shipments 50% Time savings in invoicing 70% Shortened delivery cycle time by 50% Annual cost saving in invoicing 1000 USD
Case C in RosettaNet Japan (2003)	4A4, 4A5, 4C1	Shortened the time from planning to shipping by 40% Reduced probability of human error Increased accuracy of forecast by 5% Reduced inventory loss
Case D in RosettaNet Japan (2003)	2A1, 3A4, 3A7, 3A8, 3A9, 3B2, 4A3, 4A5, 4B2	Shortened forecast-to-supply time by 67% Minimized excess inventory Shortened delivery lead time of order information Shortened procurement lead time Annual cost saving in notification of shipments 30000 USD

Yen et al. (2004) studied Eastman Chemical Company, which had established over 20 system-to-system connections with its key business partners, electronic sales were approaching 30% of total annual sales, and more than 30% of total procurement for direct and indirect materials was performed electronically in 2001. Since it was critical to Eastman's business to acquire rapid, accurate external data for planning purposes, XML-based supply chain integration was strategic. It was fundamental to this strategy to increase flexibility to market changes and, especially, to optimize the working capital. Since 1999, Eastman has invested heavily in its IT infrastructure. To encourage integration, Eastman also offered some software licenses to its business partners free-of-charge. Installation and training for integration typically took 8-12 weeks. Before an XML-based version of CIDX was introduced in 2001, Eastman had to work with its own agreed definitions for business documents. By the end of 2001, Eastman reported monthly volumes in excess of 30000 XML documents. By the middle of 2002, Eastman allowed the placing of orders, order changes and order cancellations as well as the issuing of order acknowledgments, shipping notices, invoicing and payment notices. This concept took off much more quickly in the US, whereas the Asia-Pacific region presented some new challenges. One of the major challenges was that the companies had an insufficient IT infrastructure to fully benefit from integrating with Eastman. Complex business interactions including understanding CIDX and agreeing on the business processes also presented challenges. A modest percentage of Eastman's business partners comprised 50% of the total volume of the exchanged purchase orders and sales orders. Eastman benefited from XML-based supply chain integration to initiate purchase orders. Eastman was confident that this would deliver productivity gains of 7% in the procurement of direct materials through its supplier portal. All that the supplier required was a browser-based system. This solution worked with the non-strategic business partners as well as companies having an insufficient IT infrastructure.

Auramo et al. (2005) conducted a survey of 48 Finnish companies to identify what IT solutions they have implemented in SCM. This was followed by 18 in-depth case studies to identify the mechanisms for achieving benefits of IT in SCM. Auramo et al. (2005) show that EDI-based or XML-based supply chain integration can improve information quality and agility of the supply chain network. In addition, EDI-based supply chain integration seems to be "alive and well".

Lu et al. (2006) studied Cisco and Xiao Tong, two companies that established XML-based supply chain integration using RosettaNet. In 2001, Cisco chose Xiao Tong, one of its four first-tier distributors in China, in the integration project because Cisco was Xiao Tong's biggest supplier. The revenue of Xiao Tong was responsible for 11.8% of Cisco's revenue in China. For Xiao Tong, about 60% of its transactions was related to Cisco's products. This integration project was mainly related to purchase order execution between Cisco and Xiao Tong, including product information update, product configuration, purchase order submission, purchase order status update and invoice pre-check-in. The benefits for Cisco through Xiao Tong's implementation of XML-based supply chain integration appeared in the form of more accurate information on inventory, sales quality per product and sales speed. The cycle from sales orders to purchase orders was around three days in the old purchase order process and the new purchase order process had been reduced to two and a half days. The related cost saving was the equivalent of 33000 USD annually. In addition, the managers expressed satisfaction with XML-based supply chain integration of their ability to improve decision making, as indicated in the increase of the pre-figure of 3.00 to the post-figure of 4.33 on a five-point scale. The satisfaction concerning strengthening of the relationship between Cisco and Xiao Tong was increased from 3.12 to 4.12 on a five-point scale. Since the motivation of Xiao Tong was relatively weak, the pressure from Cisco was the main reason why Xiao Tong agreed to implement an XML-based integration system. To win the active participation of Xiao Tong in the integration project, Cisco covered all software cost for Xiao Tong, amounting to about 350000 USD, and promised to return some profits to Xiao Tong to compensate for the costs of the implementation. Critical success factors for supply chain integration over the

Internet are very similar to those for supply chain integration over the VANs. Although the Internet offers much more flexibility and a cheaper way to develop and operate supply chain integration, much can be learned from the experiences of developing, implementing and operating supply chain integration over the VANs. Because of RosettaNet, the implementation of supply chain integration between Cisco and Xiao Tong was very efficiently carried out and at low costs. For this reason, RosettaNet was considered as one critical success factor.

2.3.5 Literature revised

The literature contains a large number of papers on experiences from EDI-based supply chain integration. With regard to XML-based supply chain integration, the situation is different. Considering how much effort has been devoted to developing XML technologies and XML-based e-business frameworks, it is amazing how few experiences from XML-based supply chain integration have been publicly reported. Except for Chiu and Chen (2005), the studies dealing with the integration system prototypes concentrate on the technical aspects, whereas the studies on the operative integration systems focus on the business aspects. The latter studies mostly provide qualitative results and are mainly limited to RosettaNet.

Many papers study the properties of XML-based e-business frameworks. However, the standardization of XML-based e-business frameworks has received little attention. In fact, the EDI and XML formats have not received nearly as much attention as the QWERTY and DSK layouts in the literature of standardization. There is also no agreement on the existence of network externalities and the relevance of path dependences, although they play an important role in this literature.

Goldfarb and Prescod (2003), Gosain et al. (2003), Hsieh and Lin (2004), Jones (2001), Power (2005) and Reimers (2001) have regarded XML as more flexible and less expensive to implement or use than EDI. XML has been seen as flexible, human-readable, self-describing, structured and inexpensive. It also separates the processing from content and can be used over the Internet. All these arguments are relevant in web publishing but not necessarily in supply chain integration. According to Kanakamedala et al. (2003), Wareham et al. (2005) and Wilson (2000), the benefits of XML do not outweigh its costs or XML is not replacing EDI in the near future. Unfortunately, the comparison between EDI and XML is not straightforward. EDI-based supply chain integration has been traditionally implemented with older programming languages (e.g. Cobol) over the VANs and XML-based supply chain integration with new programming languages (e.g. Java) over the Internet. In addition, EDI-based supply chain integration is increasingly carried out over the Internet (Angeles 2000, Threlkel and Kavan 1999). In 1997, IETF introduced EDI Internet Integration (EDIINT), which supports the secure exchange of data represented in the EDI format over the Internet. The comparison should not be between the VANs and Internet but between the EDI and XML formats or EDI-based and XML-based e-business frameworks.

There seems to be no paper that has studied the role of XML-based e-business frameworks in e-business adoption or migration. There are few papers studying the adoption of e-commerce or the migration to Internet-based e-commerce. Zhu et al. (2003) analyze facilitators and inhibitors of e-business adoption. The sample includes 3552 companies from eight countries in Europe. The firm size, firm scope and technology competence are significant facilitators, whereas a lack of business partner readiness is a significant inhibitor of e-business adoption. Based on 6165 establishments of the companies over three years period, Forman (2005) concludes that the firm size and firm scope increase the likelihood of Internet application adoption, including e-commerce. Hong and Zhu (2006) assess Internet-based e-commerce adoption. The usable sample covers 627 companies from the US and Canada. The web functionalities and technology integration are significant drivers in Internet-based e-commerce adoption. The firm size is found to affect this adoption negatively. Based on 239 companies, Hong and Zhu (2006) also show that the web functionalities and integration of externally-oriented enterprise information systems, such as SCM and CRM, are significant drivers in Internet-based e-commerce migration. The firm size and VAN usage are found to affect this migration negatively. Zhu et al. (2006) investigate the migration to more open information systems, i.e. information systems connected through the Internet, from less open information systems, i.e. information systems connected through the VANs. The sample consists of 1394 companies from ten countries. The expected benefits are significant drivers in the migration to more open information systems. In addition, the costs are a more significant barrier for users of less open information systems than for others.

3 Results

This section contains the results of the thesis. The more concrete and specific analyses are presented first and the more abstract and generic last. Subsection 3.1 focuses on an integration system prototype called Communication Application (CA), which was implemented for XML-based supply chain integration and evaluated within an industrial case (II). This subsection starts from the case companies and requirements, introduces the architecture and functionalities of the CA and ends with the evaluation results in the industrial case. Subsection 3.2 analyzes properties of XML-based e-business frameworks and their standardization (III). This subsection presents three variables related to the properties of the e-business frameworks, four variables related to their standardization, possible values for these variables and a summary of these e-business frameworks on the basis of these variables and values. This summary is utilized to find out commonalities and regularities that are explained and compared with the findings presented in the literature. Subsection 3.3 compares the use of the EDI and XML formats in e-business frameworks and the use of these e-business frameworks in companies (IV). To what extent do SDOs use the EDI and XML formats in e-business frameworks? To what extent do companies use EDI-based and XML-based e-business frameworks? This subsection answers these questions and discusses some findings presented in the literature. Subsection 3.4 explores how organizational and technological factors including EDI-based and XML-based e-business frameworks explain the adoption of e-business functions and the migration from EDI-based to XML-based e-business frameworks (V). A linear regression analysis is used to study the adoption and a logistic regression analysis to study the migration. The results of these analyses are compared to findings presented in the literature.

3.1 XML-based integration system prototype in industrial case

3.1.1 Research approach

Publication (II) is based on design science and case study research. *Design science* research has a long tradition in engineering research. According to March and Smith (1995), to make significant progress, research must develop an understanding of how and why systems work or do not work:

- An artifact is *built* to perform a specific task. The basic question is whether it works. Building an artifact demonstrates its feasibility in the task.

- The artifact is *evaluated* to determine if any progress has been made. The basic question is how well it works. Progress is achieved when an artifact replaces a less effective artifact. Evaluation requires development of metrics and measurement of the artifact according to those metrics. Metrics define what one tries to accomplish. They are used to assess the performance of the artifact.

Case study research is a common methodology in business research. According to Yin (1994), a case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and its context are not evident.

Publication (II) presents an XML-based integration system prototype called CA that was designed and implemented using open-source Java and XML technologies. The CA was also experimented and evaluated within an industrial case. Three versions of the CA were implemented and evaluated. The preliminary versions of the CA were presented at international conferences (Seilonen et al. 2001, Nurmilaakso et al. 2001) whose participants were researchers of e-business, information systems and SCM. The feedback given at these conferences has helped improve the implementation and evaluation of the final version of the CA. The CA was implemented to study the feasibility of XML-based supply chain integration. To study the benefits and costs of the XML-based integration systems, the CA was evaluated within an industrial case, in which the main contractor of the production network was ABB Control. The other companies of this production network were subcontractors and suppliers of the main contractor. One of these subcontractors, InCap Electronics, was also involved in the industrial case. Originally, there was no intention to carry out detailed evaluation of the CA because only ABB was officially a case company. Fortunately, InCap was kindly willing to participate in the evaluations. During the experiments, the CA resided at ABB and users from ABB and InCap had access to the CA over the Internet by a web browser. Since it was not possible to install and maintain the CA at InCap, business interactions between two integration system prototypes were not experimented in this industrial case. However, this kind of experiment was carried out over an intranet in the laboratory environment. Since ABB and InCap were using EDIFACT for exchanging a part of their purchase orders, purchase order responses and invoices, the industrial case provided an opportunity to compare XML-based and EDI-based supply chain integration. xCBL 2.0 was used as an XML-based e-business framework for this purpose.

The evaluation plan was originally drafted on the basis of a set of assumptions about XML-based integration systems, such as the CA. The main hypothesis was that they could provide a sound basis for supply chain integration between companies. It was also hypothesized that XML-based integration systems could be more flexible to maintain and use and less expensive to implement and operate than EDI-based integration systems. On the basis of these hypotheses, it was considered that SMEs especially would be interested in XML-based integration systems, provided that their benefits could be identified and illustrated in a proper way. In consequence, it was also considered that even larger companies might regard XML-based integration systems as feasible extensions to their existing supply chain integration when collaborating with SMEs. An objective of the evaluation was to assess the correctness of these hypotheses.

The evaluation was conducted in the form of a two-tier cost-benefit analysis. The first phase of the evaluation focused on the industrial case, whereas the second phase generalized the case-specific results. The idea was to produce more generic information on the potential benefits and costs of the XML-based integration systems. The main methodological challenges related to the identification and assessment of the potential benefits and costs of an XML-based integration system that was not operative at the time of the evaluation. The evaluation methodology was largely developed as the work in the industrial case progressed. Important methodological references included Anandarajan and Wen (1999), Luoma et al. (1999), Willcocks and Lester (1999a, 1999b) and Zuboff (1988). Special emphasis was on developing methods that would make it easier to concretize what a corresponding operative system would be able to do if it were actually brought into production use at ABB. Not only demonstrations with the CA but also discussions with the case companies' representatives had an important role in the evaluation. Different kinds of models, such as interaction diagrams, were used to describe the functionality of the CA and to facilitate the analysis. Six groups of factors were identified as important contributors to the viability of the integration system prototype by evaluators. The following groups were given special emphasis in the evaluation:

- *Functionality and technical feasibility*: This area of the evaluation aimed at assessing the applicability of the chosen mechanism to mapping business documents in different data formats to each other. In addition, attention was paid to the functioning of the implemented business interactions as well as to the overall technical feasibility of the CA.

- *Scope of business interactions*: This area was more theoretical in nature and related to the chosen architecture and its configuration mechanism. The objective was to determine the extent to which they could possibly cover ABB's needs in subcontracting and related collaboration.

- *Business impacts*: The objective was to identify the potential business benefits as well as the expected disadvantages of operating a CA type of integration system at ABB. Areas, such as flexibility, reliability, efficiency, speed and costs, i.e. the key attributes of any process or practice, were addressed during the evaluation.

- *Demands of implementation*: The objective was to identify the challenges and needs for change that the implementation of a CA type of integration system might cause in ABB's processes, practices and organization.

- *Configuration and maintainability*: The main objective was to determine the basic requirements for the definition and modification of business interactions in terms of the necessary knowledge and work inputs. Another related objective was the specification of feasible arrangements for the initial configuration process and the related systems support.

- *Use of EDI*: The objective was to examine the utilization of the EDI-based integration system at ABB, to identify its main benefits and support for purchasing processes and practices and to construct an extensive picture of all EDI-related implementation and operating costs. The purpose of analyzing the use of the EDI-based integration system was to establish a kind of reference point for the CA.

In the evaluation, there were no particular reasons to worry about possible respondent bias because neither of the case companies' representatives were responsible for implementing the CA, nor were they committed to bringing it into production use. It was concluded that the given estimations were sincere and based on the best available knowledge and experience at that time. The case companies' representatives as well as the developers of the CA reviewed the evaluation results. Some of these evaluation results were based on confidential information and, therefore, not published in the original form.

A lack of researchers capable of implementing or evaluating an XML-based integration system prototype caused limitations, given the research budget and schedule. Five functionalities were implemented in the CA and six business interactions were evaluated within the industrial case. One of the functionalities was implemented only in and one of the business interactions was evaluated only with the final version of the CA. Some important security and reliability properties were not implemented in the CA. The case companies and specification of xCBL 2.0 did not require these properties. A number of important business interactions were identified but ignored. The industrial case covered business interactions related to the exchange of purchase orders, purchase order responses and invoices, which were the most common EDI message types in Finland (Kärkkäinen et al. 2001). Since xCBL was ahead in the development of XML-based e-business frameworks in 2000, it was used in the industrial case.

3.1.2 Industrial case

ABB Control has a switchgear factory that is located in Vaasa, Finland. ABB Control is a part of the global ABB group and it produces switchgear assemblies for both internal and external use. The application area of switchgears is power distribution and control. Their purpose is to protect low voltage motors in the process industry. A switchgear order is called a project that consists of functional units. The order may include one switchgear with one functional unit or many switchgears with hundreds of functional units.

ABB Control has an in-house system called Customer-oriented Process Information System (COPIS), which manages many aspects of the order-delivery process related to a switchgear order. The functionality of COPIS covers engineering design, product configuration, material requirements planning (MRP), production planning, quotations and order tracking. It makes quotes and production resource predictions based on labor requirements.

Many of ABB Control's customers require switchgear orders at short notice. The company policy is to deliver special customer-tailored solutions by the requested day. ABB's switchgear factory in Vaasa often works very close to or over full capacity and over the last few years the final delivery dates have not been met in some orders. Production planning with a short delivery time is difficult.

The order-delivery process related to a switchgear order is quite traditional in ABB Control. The customer sends a tender request to sales persons or the sales department.

The planner feeds the technical data of the tender request into COPIS and configures the switchgear unit. After that, COPIS develops drawings and the tender is sent to the customer. If the customer accepts the tender, all the data and information are available from COPIS. Using COPIS, ABB Control has visibility of the present factory loading and anticipated loads. When the loads threaten to exceed the factory capacity, the management looks for alternative production resources in order to clear the overload. ABB Control has several methods for outsourcing the production. These are local ABB outsourcing, i.e. ABB companies in Finland, global ABB outsourcing, i.e. ABB companies world wide and subcontracting.

InCap Electronics in Vaasa is one of ABB Control's subcontractors providing production resources for switchgear assembly. It is also a subcontractor for ABB Drives and ABB Industry, for example. Although the InCap Electronics factory is located inside the ABB Control factory in Vaasa, InCap Electronics and ABB Control use EDI to exchange some business documents.

The basic requirement was to continue using COPIS but expand its functionality relative to production management and purchasing in respect of the internal and external production resources. Internal production resources mean ABB Control's own capacity, whereas external production resources mean capacity of other ABB companies or subcontractors. The combination of internal and external production resources forms a supply chain. The integration system prototype extends the functionality of COPIS to support supply chain integration.

The idea behind the supply chain integration is flexible transparency of the internal and external production resources. With this transparent view of the production resources, the production management has the opportunity to plan external resources as internal ones. For ABB Control, the expected business benefits through the supply chain integration are related to the growing production flexibility and more profitable exchange of data. Figure 8 illustrates a cooperation model in which a subcontractor produces ABB-specific products, whereas a supplier does not. This cooperation model of supply chain integration could be implemented with the current software technologies. A number of commercial integration systems, such as Microsoft BizTalk Server, were available. However, taking into account the unstable status of the these systems in 2000, the industrial case gave an opportunity to design and implement an integration system prototype called CA. The objective was to achieve an integration system prototype that can be easily maintained and used and to utilize XML technologies. With XML, the purpose was to extend supply chain integration to those subcontractors who had not accepted EDI-based supply chain integration. It was also assessed that, perhaps later, the XML format could be used to replace the EDI format.

The architecture of the CA was based on a model in which a server supports EDI, XML or both data formats. The clients of this server can be web browsers, other integration systems or other information systems. This was not the only possible model but many commercial integration systems at least partially conform to this architecture. The implementation of supply chain integration required the design of the required messages and their interaction-handling logic.

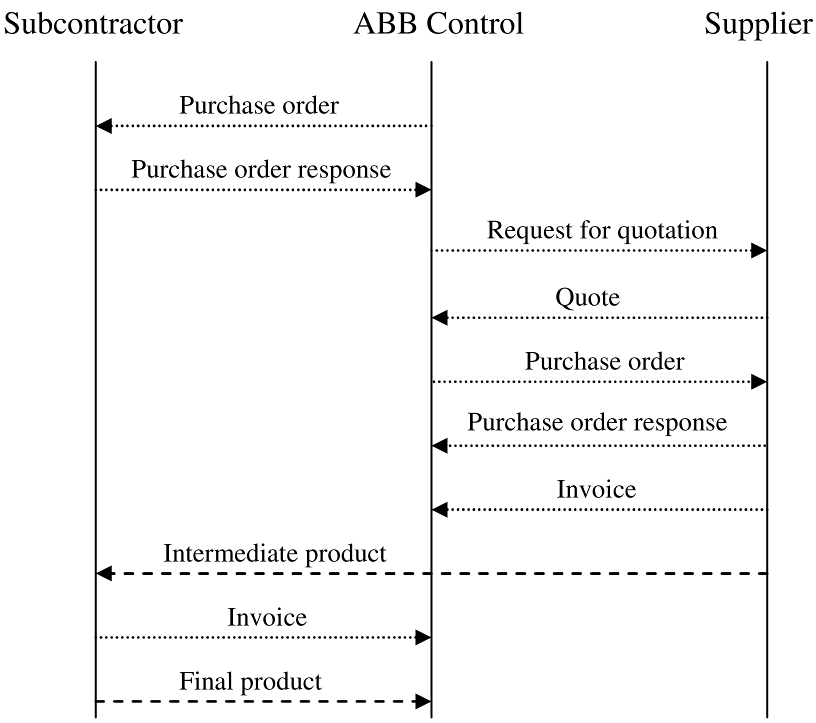

Figure 8: A cooperation model

A large number of potentially useful business interactions were identified in the industrial case for supply chain integration. Some of these business interactions were primitive. In the industrial case, the objective was that the CA is capable of performing the following business interactions:

1. *ABB sends a specific purchase order to a specific subcontractor.* Query the database for the EDIFACT message of a purchase order, translate the purchase order from the EDIFACT message to the xCBL document, send this purchase order in the xCBL document using an e-mail or a message to the subcontractor and a return success/failure status.

2. *A subcontractor queries for one of its purchase orders by a web browser.* Query the database for the EDIFACT message of a purchase order, translate the purchase order from the EDIFACT message to the xCBL document and return the purchase order.

3. *A subcontractor queries for a list of all its purchase orders by a web browser.* Query the database for the EDIFACT message of purchase orders, translate the purchase orders from the EDIFACT message to the XML document and return a list.

4. *A subcontractor updates a purchase order response in the xCBL document into an ABB's database by a web browser.* Translate the purchase order response in the xCBL document to the SQL Insert statements for the EDIFACT message, update the database with the EDIFACT message and return a success/failure status.

5. *A subcontractor updates an invoice in the xCBL document into an ABB's database by a web browser.* Translate the invoice in the xCBL document to the SQL Insert

statements for the EDIFACT message, update the database with the EDIFACT segments and return success/failure status.

6. *A subcontractor queries for a demand forecast of all its possibly forthcoming purchase orders by a web browser.* Query for possibly forthcoming orders, translate the possibly forthcoming purchase orders from the EDIFACT message to the XML document and return a demand forecast.

All these business interactions except the last one, i.e. a query for a demand forecast, were used as a starting point in the design and implementation of the CA. ABB Control suggested them. The last business interaction was identified after the implementations of the first version of the CA and suggested by InCap Electronics. It gave an opportunity to evaluate the maintainability of the integration system prototype.

The purchase order, purchase order response and invoice documents were based on an XML-based e-business framework. xCBL 2.0 was utilized in the industrial case because it provided the corresponding business documents represented in XML format and was based to some extent on EDIFACT. XSLT was needed to make the necessary transformations between EDIFACT messages and xCBL or XML documents.

3.1.3 Integration system prototype

The integration system prototype conforms to a layered software architecture that could be described as an engine-processor architecture. The CA is integrated to other information systems using standard technologies, such as HTTP, Open Database Connectivity (ODBC) and Simple Mail Transfer Protocol (SMTP). Figure 9 illustrates the engine-processor architecture of the CA. An engine that processes the interaction requests and executes them according to the configured interaction definitions forms the top layer of the architecture. These definitions describe the interaction-handling logic in terms of parameters and operations. The bottom layer of the architecture contains a set of processors that are able to perform the operations. The CA can load these processors and their configuration data "on demand" from the local file system or the Internet. This makes it possible to maintain the functionality of the integration system prototype without code changes to the engine. In addition to portability, Java supports the previous kind of dynamic extendability. The system configuration data has to reside on the same host as the system itself, whereas all other configuration data can be retrieved from the Internet. The CA was implemented with open-source tools: Java 2 Platform Standard Edition (J2SE) (version 1.3.0), Jakarta-Tomcat servlet container (version 3.1), Java Application Programming Interface for XML Processing (JAXP) parser (version 1.0.1) and Saxon XSLT processor (version 5.4.1).

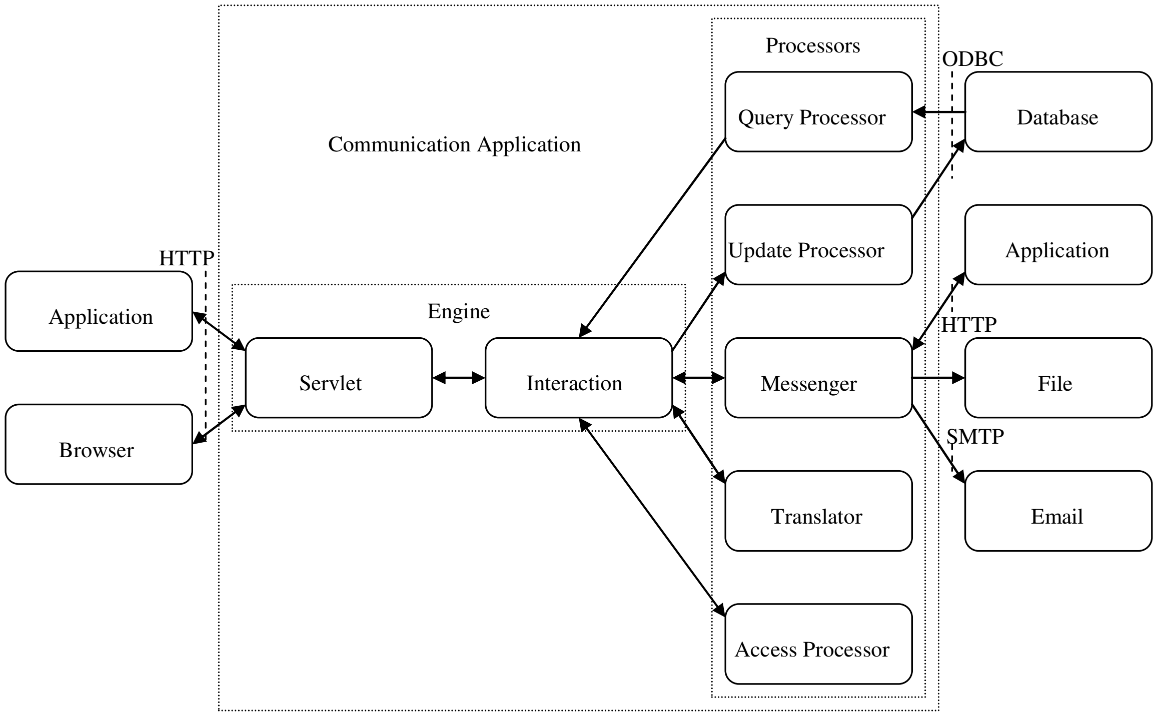

Figure 9: The architecture of the CA

The engine of the CA processes the interaction requests according to their configuration data. The processing logic is as follows:

- A *Servlet* processes the interaction requests from the clients. The requests can be in HTML or XML. According to this request, the Servlet passes the call to an Interaction, which is associated with the configured interaction definitions.

- The *Interaction* executes the requested business interactions with the given parameter values and the configured interaction definition as inputs. It interprets the XML-based configuration language and calls the processors according to the configured interaction definitions. When a processor has executed an operation successfully, it saves the output and the Interaction passes it on to another processor if necessary. When all operations of the Interaction are executed, the Interaction returns the result.

- The Servlet sends the result to the client as an interaction response. The interaction response can be presented in different formats (e.g. plain text, XML or HTML).

In the industrial case, the CA had five processors. All these processors except the last were implemented in the first versions of the CA. Their roles are presented in the following:

- The *Query Processor* retrieves data from a relational database through ODBC. Its inputs are values associated with the Standard Query Language (SQL) Select statement to be executed. The output is a result of this statement translated into the XML format.

- The *Update Processor* manipulates the data content of a relational database through ODBC. The input consists of SQL Update, Insert or Delete statements in the XML format. The processor has no output.

- The *Messenger* saves a document or sends a request to a specified target. Its inputs are either a document or a request and a target name. In the case of a request, the Messenger is left waiting for a response, which is its output. The request can be an interaction request and the target may be another integration system. In this way, it is possible to delegate the processing of business interactions between integration systems at the different sites.

- The *Translator* is an essential processor because it transforms input from one XML format into another. The output of the processor is a result of the XSLT translation specified as a part of the configuration data.

- The *Access Processor* checks the password given by the user. Its inputs are a user name and password. If the password is invalid, the processor aborts the execution. Otherwise, the output of the processor is the identification associated with the user that can be used by other processors.

A large part of the actual functionality of the CA is defined with XML-based configuration languages instead of programming languages, such as Java. This is motivated by better maintainability. However, the element or attribute names in DTDs that are used to validate configuration data cannot be changed because DTDs do not enable some checks (e.g. whether a particular element with a particular attribute value has occurred already). Therefore, some changes can be done at run-time by modifying DTDs but a lot of information related to validation of the configuration data has to be hard-coded at compile-time. Although XML-based configuration languages do not remove the problems of maintenance, they facilitate it by being without graphical user interfaces that are often expensive to develop. The configuration data is divided into three levels. At the system level, the configuration data specifies which business interactions are defined for the system. At the interaction level, the configuration data defines which parameters and operations are required for execution of a business interaction. At the operation level, the configuration language is specific to the processor that executes the operation. Interaction definitions form the core of the configuration of the integration system. A balance between flexibility and simplicity has been aimed at by defining the business interactions as operation-block models. The business interaction has parameters the values of which are given by the sender of the interaction request. These parameters are inputs for operations that are sequentially executed in the order of appearance. Each operation has a link to the processor that executes the operation with the given configuration and inputs. Some operations return output that works as input for the following operations or as a result of the business interaction.

The following example shows the configuration of the CA at the system and interaction level. In this example, a user wants to get information on a purchase order. Figure 10 shows the configuration data at the system level. An interaction is identified by an operation-content-document-triple that refers to the interaction definition. The example demonstrates a query-xcbl-order-interaction whose definition is located in “file://query-xcbl-order.xml”.

```
<configuration dtd="file:request.dtd" html="file:xml-to-html.xsl">
  <interaction operation="send" content="xcbl" document="order">
    file:send-xcbl-order.xml
  </interaction>
  <interaction operation="query" content="xcbl" document="order">
    file:query-xcbl-order.xml
  </interaction>
  <interaction operation="receive" content="xcbl" document="invoice">
    file:receive-xcbl-invoice.xml
  </interaction>
</configuration>
```

Figure 10: An engine configuration

Figure 11 illustrates an interaction definition that has both parameters as input and a result as an output. In the example, parameter values user, password, and order-id are given by an interaction request. The first operation, access, has configuration data that is located in “file://query-xcbl-order-access.xml”. The program code of this operation is located in “file://AccessProcessor.class”. The access operation checks the username and password. If they are valid, the execution proceeds to the second operation, query. This operation retrieves the EDI message for a purchase order with a value order-id from a relational database and represents the result as a result set in the XML format. The third operation, translation, transforms the output of the query operation into xCBL. Finally, the interaction returns the output of the translation operation that is transmitted to the user as the interaction response.

```
<interaction-definition>
  <parameter name="user" type="String"/>
  <parameter name="password" type="String"/>
  <parameter name="order-id" type="String"/>
  <operation name="access"
    processor="file:AccessProcessor.class"
    configuration="file:query-xcbl-order-access.xml">
    <input name="user"/>
    <input name="password"/>
  </operation>
  <operation name="query"
    processor="file:QueryProcessor.class"
    configuration="file:query-xcbl-order-database.xml">
    <input name="order-id"/>
  </operation>
  <operation name="translation"
    processor="file:Translator.class"
    configuration="file:query-xcbl-order-translation.xsl">
    <input name="query"/>
  </operation>
  <result name="translation"/>
</interaction-definition>
```

Figure 11: An interaction definition (query-xcbl-order.xml)

At the operation level, the configuration data can be presented in many different ways. Although a processor may have very sophisticated needs considering configuration, it is recommended that the configuration data is represented in the XML format. From the viewpoint of maintainability, the hierarchical structure of the configuration data has an advantage by providing independence between the different levels. For example, if the passwords of the users are changed, there is no need to make changes at the system or interaction level. On the other hand, if the access check is removed, the configuration data remains the same at the system level.

3.1.4 Evaluation of feasibility

The first objective of the evaluation was to find out how and to what extent the CA could support supply chain integration between companies.

Finding 1: The industrial case suggested the feasibility of XML together with the chosen architecture and configuration mechanism as an implementation approach to the integration system.

The implementation process of the CA appeared to be flexible due to the fact that the interaction definitions are stored in text files that can be created and maintained by means of ordinary text editors. Functional tests of the implemented business interactions were completed successfully, including those that were run over the Internet. However, with regard to purchase order, purchase order response and invoice documents, the content checks revealed some disparities between the corresponding business documents in EDIFACT and xCBL. The identified deviations mostly related to differences between these e-business frameworks, which actually made a perfect match impossible. Compared to EDIFACT, xCBL did not make the difference between the net and gross price in the purchase orders and invoices. xCBL also required information about the document language. This indicated the disparity of EDIFACT and xCBL. Usually, such problems can be resolved because data structures can be flexibly added to or removed from XML documents.

The chosen engine-processor architecture together with its XML-based configuration mechanism proved to function well and to form a good basis for further development of XML-based integration systems. Configuration of the CA required a lot of background information. Getting this information required work and took time. In the industrial case, the total amount of time needed for defining one business interaction was reported to range from a couple of hours up to a couple of weeks. The large variation related mostly to the complexity of XSLT translations determined by the characteristics of the data structures to be mapped to each other. A rough estimate was that about 80% of the XSLT translations were easy to write, whereas the remaining 20% required considerably more effort at least in the learning phase. The translation was often considerably facilitated by splitting it into a sequence of translations. It was estimated that, on average, the interaction definition takes around one week of work. In some cases, only about 5% of the time was actually spent on writing the interaction definitions. These were based on the developers' estimate, provided that the work is done by an expert with a good knowledge of XML, XSLT and xCBL, with a profound understanding of the integration system and with no previous knowledge of the company's information system to which the integration system is to be connected. These conditions applied to the evaluators and developers of the CA. In addition, the business documents have to be specified in advance, as they were in the industrial case, apart from one business interaction. If the configuration process involves business planning (e.g. negotiations between several business partners on the business documents), then much more time will be needed. In the course of time, things get easier due to the learning effect. For example, modifications to the existing business interactions were performed fluently. The existing interaction definitions also formed a good basis for the definition of new ones of a similar kind.

3.1.5 Evaluation of benefits and costs

The second objective of the evaluation was to assess the viability of the CA by identifying its potential business benefits and expected implementation and operating costs.

Finding 2a: The business benefits of the XML-based integration system prototype were to a small extent higher than the benefits of the EDI-based integration system in the industrial case.

The industrial case suggested that the business benefits of integration systems in general are highly dependent on the scope of their implementation and on case-specific needs. In the case of ABB, they mostly related to production planning and control as well as the functioning of the customer interface. In consequence, ABB was especially interested in the possibility of exchanging information related to the subcontractor's capacity and order status. The assessed benefits were related to enhanced information management, more efficient use of the available production resources and shorter lead times. InCap emphasized the importance of demand forecasts as a medium in its production planning practice. All business interactions that were identified as potentially useful by ABB were either implemented or could have been implemented in the CA. Some of those business interactions were not supported by EDIFACT and only a few of them were actually used in Finland. With regard to purchase orders, purchase order responses and invoices, the expected benefits were similar to those of the EDI-based integration system (e.g. higher efficiency of administrative routines). Of other useful business interactions, order lists and demand forecasts were implemented in the CA. The XML format facilitated their implementation in the business documents and their configuration in the CA.

Finding 2b: The implementation and operating costs of the XML-based integration system prototype were lower than the costs of the EDI-based integration system in the industrial case.

When assessing the potential starting points for implementing the CA, two different scenarios were identified: establishing a new connection or replacing an existing connection between ABB and one of its subcontractors. The general conclusion was that in both scenarios the demands of implementation on a company would be very similar but two special characteristics were identified. The first special characteristic relates to the utilization of the Internet instead of the VANs. On one hand, there would be no VAN operator between the two companies, which in turn would probably result in significant savings in the communication charges. On the other hand, it is up to the user companies to establish a proper solution for managing the connection. In the VANs, the VAN operator provides this solution. It was not clear how much a corresponding Internet-based solution might cost. The second special characteristic has to do with the industrial case when the subcontractor decides to operate the integration system through a web browser instead of an integration system of its own. In such a case, the subcontractor's implementation process would be relatively straightforward. From the main contractor's viewpoint, this scenario involves several uncertainties. For example, erroneous messages are more likely to end up in operative information systems causing excess administrative work. There is no obvious solution to this challenge, although proper training is certainly a key issue. However, it can be reckoned that the main contractor would have to invest more time and resources in supervising the use of the integration systems.

The implementation costs of EDI-based supply chain integration were assessed to be higher than the costs of the CA. With regard to the amount of necessary work alone, the introduction of a new EDI message type that corresponds to the definition of a new business interaction in the CA was found to require a new EDI module and about 200 hours of related specification and testing work. Opening a new connection, i.e. taking a particular message type in use between two companies, was found to require a couple of days of testing. Provided that the testing times were about the same with regard to the EDI-based integration system and CA, it was estimated that implementing a new EDI message type was at least three to four times more expensive than implementing a new business document with the CA. This was based on the ABB system specialists' experience on EDI development.

In 2001, Finnish software vendors showed interest in the CA but they were not able to give any estimate of the order of the future license fees for a CA type of commercial integration system. When the communication charges are taken into account, the XML-based integration system seems to have lower operating costs because it is based on the use of the Internet. However, it is difficult to say whether the communication charges for XML-based integration systems could be commensurate with those of EDI-based integration systems.

3.2 XML-based e-business frameworks and their standardization

3.2.1 Research approach

Publication (III) analyzes 12 prominent XML-based e-business frameworks to identify the key variables and values related to their properties and standardization. This publication also identifies the relationships between the values of these variables and explains why these relationships exist. The preliminary results of the analysis were presented in an international workshop (Kotinurmi et al. 2003) whose participants were researchers of ICT standards and standardization. The feedback given in this workshop has provided the opportunity to improve the analysis. Of the dozens of XML-based e-business frameworks, CIDX, cXML, ebXML, OAGIS, papiNet, PIDX, RosettaNet, Universal Business Language (UBL) (OASIS 2004c) and xCBL were chosen. This sample was extended by BPEL, Business Process Modeling Language (BPML) (BPMI 2004) and XML Process Description Language (XPDL) (WfMC 2004). All these e-business frameworks support industrial procurement, design, production or distribution and had active standardization in 2004. The sample of XML-based e-business frameworks contains both pioneers, such as OAGIS and xCBL, newcomers, such as BPEL and UBL, as well as e-business frameworks that have been in the limelight, such as ebXML and RosettaNet. The chosen e-business frameworks can be regarded as successes rather than failures. Each one of them is supported by one or more software providers, such as BEA, Fujitsu, IBM, Microsoft, Oracle and webMethods.

The analysis was primarily based on the specifications of the e-business frameworks but also used other information available on the web pages of the e-business frameworks, such as information on members, organization, intellectual property rights (IPR) and news. The literature was also analyzed to identify key variables and their possible values and to assign these values to the variables. First, three variables related to the properties of the e-business frameworks, four variables related to their standardization and possible values for these variables were identified. Then, these e-business frameworks were summarized on the basis of these variables and values. This summary was based on the situation at the end of 2004. The summary was utilized to find out *commonalities* and *regularities* between these e-business frameworks and their standardization. The selection of cut-off points in any analysis is somewhat arbitrary. The lower and upper quartiles are measures often used to summarize a sample set. Based loosely on these measures, one quarter and three quarters were selected as cut-off points to indicate regularities and commonalities. For a commonality, one variable has the same value for more than three quarters of e-business frameworks. For regularity, two or more variables have the same values for more than one quarter but at most three quarters of e-business frameworks. Finally, these commonalities and regularities were explained.

For the properties of the XML-based e-business frameworks, three technical key variables have been identified, as presented in publication (I) as well as by Medjahed et al. (2003). The variables have three values including no value. These values are assigned to the variables, as shown in Table 4.

- *Business documents - what information should the business partners share?* If the e-business framework follows the *specific* document approach, it defines the particular business documents to be represented in XML. If the e-business framework is based on the *generic* document approach, it provides means to define the business documents.

- *Business processes - when should the business partners share information?* If the e-business framework is based on the *specific* process approach, it defines the particular business processes. If the e-business framework follows the *generic* process approach, it provides means to define the business processes to be represented in XML.

- *Messaging - how should the business partners share information?* If the e-business framework covers messaging, either *MSG* or *RNIF* is used.

Table 4: Properties of XML-based e-business frameworks

E-business framework	*Business documents*	*Business processes*	*Messaging*
BPEL		Generic	
BPML		Generic	
CIDX	Specific	Specific	RNIF
cXML	Specific	Specific	
ebXML	Generic	Generic	MSG
OAGIS	Specific	Specific	RNIF
papiNet	Specific	Specific	MSG
PIDX	Specific	Specific	RNIF
RosettaNet	Specific	Specific	RNIF
UBL	Specific	Specific	
xCBL	Specific	Specific	
XPDL		Generic	

Jakobs (2002) and Shapiro and Varian (1999) offer a starting point to identify non-technical key variables. The four variables characterize standardization of the XML-based e-business frameworks. Two to three alternative values have been identified for these variables. Table 5 presents the values assigned to the variables.

- *Industry - what kind of use is the e-business framework directed to?* If the standardization aims to cover all industries, the e-business framework is a *cross*-industry one. Respectively, the e-business framework is an industry-*specific* one if its standardization focuses on one or a few industries. The specifications of the e-business frameworks express whether the e-business framework is industry-specific or not.

- *Drivers - what kinds of members drive the standardization?* Software vendor and consulting companies, other companies and non-profit organizations are members involved in the standardization of e-business frameworks. In some cases, there is a difference between full members, who have to pay for their membership and may have greater power in the standardization, and other members. In other cases, all members are full members but they may not have to pay for their membership. If the majority of full members are software vendor and consulting companies, the *vendors* drive the standardization of the e-business framework. Respectively, the *users* drive this standardization if the majority of full members are other companies. Otherwise, the standardization is *neutral*.

- *Organization - how is the standardization organized? Formal* standardization is based on an SDO. This is a non-profit organization, in which the board and rules guide its members who prepare the standardization work. *Informal* standardization allows companies that want to be members involved in the standardization to do their work without an additional organization. It is also possible to differentiate between a formal and an informal organization because either the SDO or the companies have IPRs of the e-business framework.

- *Openness – to what extent is the e-business framework open?* At one extreme, the e-business framework is fully *open* if it is subject to no IPRs. At the other extreme, the SDO or companies use patents, trademarks or copyrights to exercise *control* over their e-business framework. The e-business framework can also be *semi*-open if the SDO or companies have copyrights to the e-business framework but they as licensors grant perpetual, non-exclusive, royalty-free rights to publish, use and implement the e-business framework without warranty of any kind. As conditions of the membership or license, the members and licensees must agree not to use the e-business framework in any misleading manner and not to assert any IPRs against the licensors or any others to publish, use or implement the e-business framework.

Table 5: Standardization of XML-based e-business frameworks

E-business framework	*Industry*	*Drivers*	*Organization*	*Openness*
BPEL	Cross	Vendors	Formal	Semi
BPML	Cross	Vendors	Formal	Semi
CIDX	Specific	Users	Formal	Semi
cXML	Cross	Vendors	Informal	Semi
ebXML	Cross	Vendors	Formal	Semi
OAGIS	Cross	Vendors	Formal	Semi
papiNet	Specific	Users	Formal	Semi
PIDX	Specific	Users	Formal	Semi
RosettaNet	Specific	Users	Formal	Semi
UBL	Cross	Vendors	Formal	Semi
xCBL	Cross	Vendors	Informal	Semi
XPDL	Cross	Vendors	Formal	Semi

3.2.2 Commonalities in standardization

The first commonality rests on the variable *Openness* and the second on *Organization*, as shown in Table 5.

Finding 3a: E-business frameworks are limitedly open.

Although XML-based e-business frameworks follow copyright licensing, their openness is essential. In order to guarantee openness, SDOs and companies use copyrights to have limited control (Shapiro and Varian 1999). This may resemble copyleft licensing but the licensees do not have to publish the source code for their system products that utilize the e-business framework. In addition, the licensees may have no rights to modify the e-business framework. If this source code had to be published, the e-business framework might not be attractive commercially. In addition, if the members or licensees could modify the e-business framework and set IPRs unilaterally, they could extend the e-business frameworks in proprietary directions.

Finding 3b: The standardization of e-business frameworks is mostly organized formally.

Excluding cXML and xCBL, the standardization of XML-based e-business frameworks is organized formally. Therefore, standardization seems to take place more in formal settings than in informal settings (Shapiro and Varian 1999). For example, BizTalk E-business framework driven by Microsoft has been closed and BPEL, driven first by BEA, IBM, Microsoft, SAP and Siebel, was later standardized under OASIS. Formal organizations can be regarded as committees and informal organizations as markets. Since most e-business frameworks are standardized through committees, this indicates to some extent that the committees have advantages over the markets, as Farrell and Saloner (1986) have found.

3.2.3 Regularities between properties and standardization

The first regularity is based on the variables *Business documents*, *Business processes* and *Messaging* presented in Table 4 and *Industry* in Table 5, whereas the variables *Industry* and *Drivers*, as shown in Table 5, create a basis for the second regularity.

Finding 4a: Industry-specific e-business frameworks are more comprehensive than cross-industry e-business frameworks.

The industry-specific e-business frameworks define particular business documents and particular business processes as well as cover messaging. Excluding OAGIS, the cross-industry e-business frameworks are less comprehensive. Although cXML, xCBL and UBL provide particular business documents and particular business processes, they ignore messaging. BPEL, BPML and XPDL enable generic business processes. ebXML deals with messaging but focuses on generic business documents and generic business processes. Generally, the industry-specific e-business frameworks have an exact vocabulary for particular business documents and descriptions for particular business processes. In comparison, the cross-industry e-business frameworks produce less detailed specifications for more generic use.

Finding 4b: Users prefer the standardization of industry-specific e-business frameworks, whereas vendors favor the standardization of cross-industry e-business frameworks.

A user does not want to participate in lengthy standardization for all industries if its main business partners represent the same or closely related industry. When a user participates in the standardization, it usually concentrates on only one e-business framework, probably because the adoption of the e-business framework is costly. For example, StoraEnso is involved in papiNet and Nokia in RosettaNet. By participating, the users can affect the results and concentrate on the problems that are important in their situation. For vendors, the existence of an e-business framework can be important but they do not have specific requirements. Obviously, they aim to support e-business frameworks that have as many users as possible, because supporting an e-business framework requires investment in the system product development. In addition, the vendors may participate in the standardization of two or more e-business frameworks. For example, IBM and Sun Microsystems are involved in BPEL, OAGIS and RosettaNet.

In the context of XML-based e-business frameworks, there is a trade-off between performance and compatibility (Shapiro and Varian 1999). However, this trade-off is more important in business interactions between different users than between different e-business frameworks or their different versions. Shapiro and Varian (1999) have argued that large networks have advantages over small networks in adoption. If an e-business framework has more adopters than another e-business framework, the former has an advantage over the latter. This could mean that although many e-business frameworks coexist in the short run, only one e-business framework survives in the long run. A more generic e-business framework can be expected to have more potential users than a more specific e-business framework. However, not only the expectations of a number of potential adopters are vital. The value of the e-business framework depends on the number of users as well as on the number of business interactions between the users. An e-business framework used more intensively by a small number of companies can be much more valuable than another e-business framework used less intensively by a large number of companies. Although users tend to play a minor role in standardization in general (Jakobs 2002), their participation seems to be very important in the standardization of XML-based e-business frameworks. The findings indicate that users are interested in deeper use, whereas vendors stress wider use. There are different preferences not only between vendors and users but also among the users, as Jakobs et al. (1998) have noted. For example, a service company collaborates with business partners from a large number of industries, whereas a manufacturing company has business partners from a small number of industries. Therefore, the existence of only one e-business framework is not necessarily the best outcome.

3.3 Use of EDI and XML

3.3.1 Research approach

Publication (IV) studies the use of the ASC X12, EDIFACT and XML formats in e-business frameworks and the use of EDI-based or XML-based e-business frameworks in companies. It also discusses a lock-in to EDI formats in e-business frameworks and to EDI-based e-business frameworks in companies. Publication (IV) explores rather than tests hypotheses. The use of EDI and XML formats takes place in two phases. First, an SDO develops an e-business framework that is based on a data format. Finally, a company uses an information system that supports the e-business framework. This raises two questions.

To what extent do SDOs use EDI and XML formats in e-business frameworks? A comparative analysis was carried out to identify the effects of XML format on the use of ASC X12 and EDIFACT formats in e-business frameworks. A sample of 38 e-business frameworks was mainly formed on the basis of the web pages of OASIS (2005) and UNECE (2005). This sample is not exhaustive but includes EDI-based and XML-based e-business frameworks developed in the EU or US. Pre-ASC X12 e-business frameworks, such as Uniform Communication Standard (UCS) in the US, as well as pre-EDIFACT e-business frameworks, such as GENCOD in France, SEDAS in Germany and Trading Data Communications (TRADACOMS) in the UK, were excluded. Information on the development and properties of the e-business frameworks was collected from the web pages of their SDOs. For some e-business frameworks, this information had to be collected by contacting the SDOs involved in their development. The information was based on the situation at the beginning of 2006.

To what extent do companies use EDI-based and XML-based e-business frameworks? A statistical analysis was used to analyze the effects of the year, country and industry on the use of EDI-based and XML-based e-business frameworks in European companies. The data were based on two e-business surveys carried out by e-Business W@tch, which was launched to monitor the maturity of e-business across different sectors in the EU, EEA and Accession countries in 2001 by the European Commission. The second part of the e-Business Survey 2003 (e-Business W@tch 2004) consisted of 4570 telephone interviews with companies from 25 European countries within ten sectors. It was carried out in November 2003 using computer-aided telephone interview (CATI) technology. The first part of the survey was excluded because it did not deal with XML-based e-business frameworks. The e-Business Survey 2005 (e-Business W@tch 2005) had a scope of 5218 telephone interviews with companies from seven EU countries within ten sectors. It was carried out in January and February 2005 using CATI technology. The respondents in these surveys were mainly IT managers in larger companies and general managers in smaller companies. The following observations were included in the sample:

- A company has access to the Internet.

- A company does business in the old market economy, i.e. Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden or UK, or in the new market economy, i.e. Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovak Republic or Slovenia.

- A company does business in the food and beverages (NACE code: 15.1-9), textile, footwear and leather (17.1-7, 18.1-2, 19.3), publishing and printing (22.1-3), chemicals and chemical products (24.1-6, 25.1-2), machinery and equipment (29.1-5), electrical machinery and electronics (30.01-02, 31.1-2, 32.1-3), transport equipment (34.1-3, 35.1-5), construction (45.1-5), retail (52.11-12, 52.4), ICT services (64.2, 72.1-6) or business services (74.1-8) sector.

If some observations are dependent, it is impossible to make a difference between correlated variables and correlated observations. To ensure that each observation is sampled independently, i.e. a company does not appear twice in the sample, an observation was excluded if a company did business in the textile, footwear and leather (17.1-4, 17.6-7, 18.1-2) or construction (45.2-4) sector in Germany, France, Italy, Poland, Spain or UK in 2003 or in the chemicals and chemical products (24.4-5), transport equipment (34.1-3, 35.3) or ICT services (72.1-6) sector in Czech Republic or Poland in 2003. Before the statistical analysis, observations, in which a company did not know whether it used an EDI-based or XML-based e-business framework, were removed so that 7593 usable observations were left.

3.3.2 EDI and XML formats in e-business frameworks

To what extent do SDOs use EDI and XML formats in e-business frameworks? Tables 6 and 7 summarize 18 EDI-based and 20 XML-based e-business frameworks in alphabetic order. For each e-business framework, the summary covers the target, which includes a geographical area and an industry, a year in which the first version was published or the development was started, e-business frameworks, which have formed the basis of the development, and further development, i.e. whether it had ceased before 2005 or was active or inactive in 2005. The comparative analysis of e-business frameworks in Tables 6 and 7 supports one finding.

Table 6: ASC X12-based and EDIFACT-based e-business frameworks

E-business framework	**Target**	**First version (started)**	**Based on e-business frameworks**	**Further development in 2005**
AIAG EDI	North American automotive industry	1985	ASC X12	Active
ASC X12	All North American industries	1982	TDCC	Active
CEFIC EDI	European chemical industry	(1989)	EDIFACT	Ceased
CIAG EDI	North American construction industry	(1991)	ASC X12	Inactive
CIDX EDI	North American chemical industry	(1985)	ASC X12	Ceased
EANCOM	Retail industry	1990	EDIFACT, TRADACOMS	Active
EDIBUILD	European construction industry	(1991)	EDIFACT	Inactive
EDIFACT	All industries	1987	ASC X12, GTDI	Active
EDIFER	European steel industry	1992	EDIFACT	Active
EDIFICE	European electronics industry	(1986)	EDIFACT	Active
EDIPAP	European paper industry	1993	EDIFACT	Ceased
EDITEX	European textile industry	(1990)	EDIFACT	Inactive
EIDX	North American electronics industry	(1987)	ASC X12	Active
GCA EDI	North American publishing industry	(1991)	ASC X12	Inactive
ODETTE EDI	European automotive industry	1996	EDIFACT, ODETTE	Active
PIDX EDI	North American petroleum industry	(1986)	ASC X12	Ceased
RINET	European insurance industry	(1988)	EDIFACT	Ceased
VICS EDI	North American retail industry	1987	ASC X12, UCS	Active

Table 7: XML-based e-business frameworks

E-business Framework	Target	First version	Based on e-business frameworks	Further development in 2005
ACORD XML	Insurance industry	1999	ACORD, RINET	Active
BPEL	Private business processes	2002		Active
BPML	Private business processes	2001		Active
CIDX XML	Chemical industry	2000	CIDX EDI	Active
cXML	All industries	1999	ASC X12, EDIFACT	Active
ebXML BPSS	Public business processes	2001		Active
ESIDEL	European steel industry	2003	EDIFER	Active
FIXML	Financial services industry	2002	FIX	Active
GS1 XML	Retail industry	2001	EANCOM, VICS EDI	Active
IFX	Financial services industry	2000	OFX	Active
MODA-ML	European textile industry	2003	EDITEX	Active
OAGIS XML	All industries	1998	OAGIS	Active
OFX XML	Financial services industry	1999	OFX	Active
papiNet	Paper, publishing, wood products industries	2001	EDIPAP, GCA EDI	Active
PIDX XML	Petroleum industry	2001	PIDX EDI	Active
RosettaNet PIP	Electronics, ICT, logistics industries	1998		Active
swiftML	Financial services industry	2002	SWIFT	Active
UBL	All industries	2004	xCBL	Active
xCBL	All industries	1998	CBL	Inactive
XPDL	Private business processes	2002		Active

Finding 5: The EDI formats have retained a strong position in cross-industry-document e-business frameworks, whereas the XML format dominates in cross-industry-process e-business frameworks and has gained a significant footing in industry-specific e-business frameworks.

There are a larger number of XML-based than EDI-based cross-industry-document e-business frameworks. The number of XML-based cross-industry-document e-business frameworks has been even larger. For example, Microsoft's BizTalk Framework and Vitria's Value Chain Markup Language (VCML) have closed down. UNECE and ANSI have also shown their interests in the XML format. In 2001, they announced joint participation in the development of ebXML Core Components Technical Specification (CCTS), which provides a method for building business documents. For example, CCTS has been applied to UBL and Context Inspired Component Architecture (CICA), which offers a modular approach to creating XML documents based on ASC X12.

Only XML-based cross-industry-process e-business frameworks exist. These e-business frameworks provide an approach not only to automate the exchange of individual business documents but to support the execution of entire business processes. Although these e-business frameworks are newcomers, they have already received a lot of attention. For example, OAGIS and RosettaNet offer guidelines for specifying their business processes using ebXML BPSS.

The XML format challenges the EDI formats in industry-specific e-business frameworks. In the financial services industry, FIX and SWIFT have not left much room for the EDI formats. Respectively, the XML format has been more successful due to FIXML and swiftML. In the chemical, insurance, paper and petroleum industries, SDOs abandoned the further development of their EDI-based e-business frameworks after XML-based e-business frameworks were introduced. In the electronics, publishing, retail, steel and textile industries, SDOs are involved in the development of both EDI-based and XML-based e-business frameworks. In the automotive industry, the SDOs of AIAG EDI and ODETTE EDI have been jointly developing an XML-based e-business framework since 2003. In the construction industry, there are ongoing development projects of XML-based e-business frameworks that are independent of CIAG EDI and EDIBUILD. There have also been many plans to unify XML-based industry-specific e-business frameworks (e.g. CIDX and PIDX) but so far the degree of realization of these plans has been modest.

According to David (1985) and Katz and Shapiro (1985), a superior non-proprietary standard may not be adopted because an older non-proprietary standard has the advantage. Therefore, SDOs should be locked into the EDI formats in their e-business frameworks. The ASC X12 format is older than the EDIFACT format, which in turn is older than the XML format. The EDI and XML formats are also non-proprietary standards. As the use of the XML format in e-business frameworks point out, there is no significant lock-in to the EDI formats. This is hardly possible if the XML format has no advantages over the EDI formats. Firstly, EDI-based industry-specific e-business frameworks are mostly modified subsets of ASC X12 and EDIFACT. This improves the compatibility between different EDI-based e-business frameworks but impairs the possibilities of taking into account industry-specific needs. For example, GCA EDI has concentrated on the publishing industry and EDIPAP on the paper industry, whereas papiNet covers both of these industries as well as the wood products industry. Moreover, XML-based e-business frameworks (e.g. RosettaNet) are often global, whereas ASC X12-based e-business frameworks (e.g. EIDX) are indented for North America and EDIFACT-based e-business frameworks (e.g. EDIFICE) for the rest of the world, especially for Europe. Finally, there exist many XML technologies (W3C 2005). A large number of open-source tools support these technologies and IT professionals are well aware of these tools (OASIS 2005).

3.3.3 EDI-based and XML-based e-business frameworks in companies

To what extent do companies use EDI-based and XML-based e-business frameworks? Of 7593 European companies, 6030 companies did not use EDI-based or XML-based e-business frameworks, 651 companies used at least EDI-based e-business frameworks, 625 at least XML-based e-business frameworks and 287 both EDI-based and XML-based e-business frameworks. *In all, 12.4% of the European companies used EDI-based and 12.0% XML-based e-business frameworks.* Figure 12 and Tables 8, 9 and 10 summarize the extent to which the European companies have used e-business frameworks in different years, countries and industries. A difference is made between the years 2003 and 2005, old and new market economies as well as industries, taking into account industry-specific e-business frameworks. Based on Tables 6 and 7, there are no EDI-based or XML-based industry-specific e-business frameworks for the food and beverages, machinery and equipment and business services industries, only EDI-based industry-specific e-business frameworks for the transport equipment and construction industries, only XML-based industry-specific e-business frameworks for the chemicals and chemical products and ICT services industries and both EDI-based and XML-based industry-specific e-business frameworks for the textile, footwear and leather, publishing and printing, electrical machinery and electronics and retail industries.

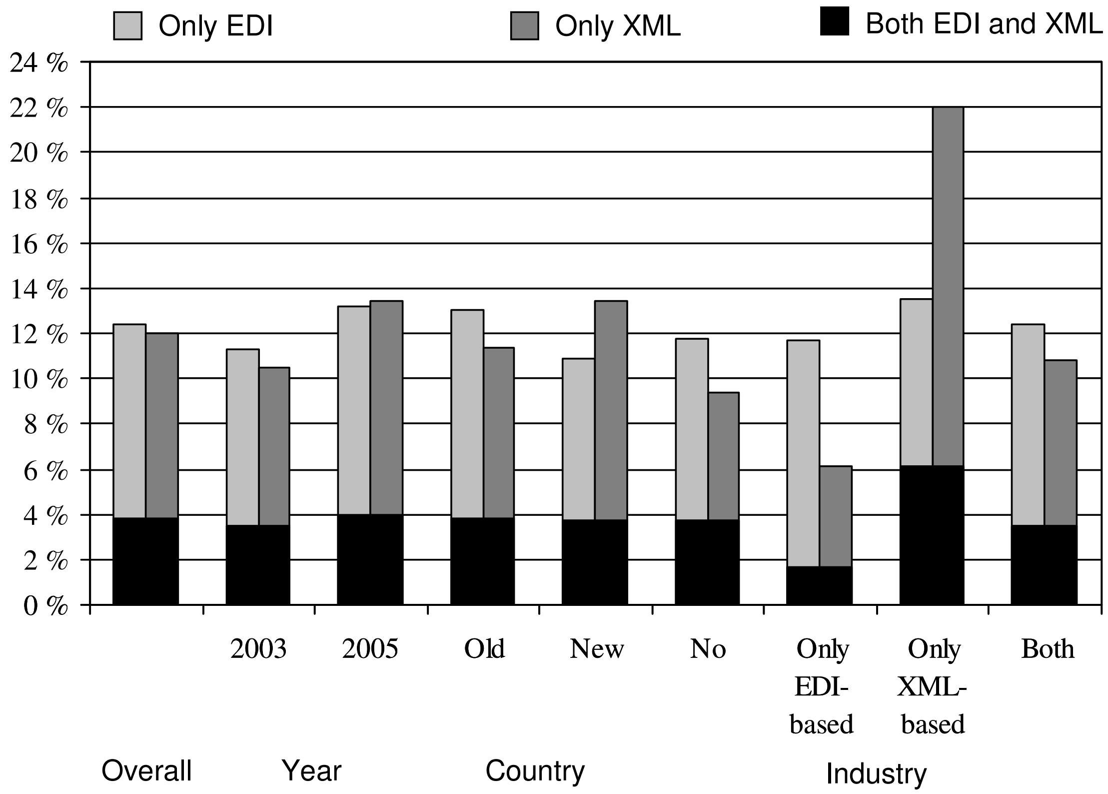

Figure 12: A histogram of the use of EDI-based and XML-based e-business frameworks

According to Pearson χ^2(*degree of freedom*) tests and contingency coefficients, there are statistically significant associations between the use of e-business frameworks and years, countries and industries at the 0.001 level ($p < 0.001$). Tables 8, 9 and 10 lead to three findings.

Table 8: The use of EDI-based and XML-based e-business frameworks in different years

Year	**Number of companies**					**% of companies**	
	No EDI or XML	**Only EDI**	**Only XML**	**Both EDI and XML**	**Total**	**EDI**	**XML**
2003	2849	274	244	121	3488	11.3	10.5
2005	3181	377	381	166	4105	13.2	13.4
Pearson $\chi^2(3)$ test (*p*-value)	21.67 (0.0)						
Contingency coefficient (*p*-value)	0.53 (0.0)						

Finding 6a: The use of EDI-based and XML-based e-business frameworks has increased in 2004. However, the use of XML-based e-business frameworks has increased more than the use of EDI-based e-business frameworks ($0 < 13.2 - 11.3 < 13.4 - 10.5$).

E-business frameworks are becoming more common in companies. This also reflects the fact that EDI-based e-business frameworks have not blocked the entry of XML-based e-business frameworks. On the other hand, XML-based e-business frameworks have not displaced all EDI-based e-business frameworks. XML-based e-business frameworks took less than a decade to achieve the degree of use that took EDI-based e-business frameworks nearly two decades.

Table 9: The use of EDI-based and XML-based e-business frameworks in different countries

Countries	**Number of companies**					**% of companies**	
	No EDI or XML	**Only EDI**	**Only XML**	**Both EDI and XML**	**Total**	**EDI**	**XML**
Old market economies	4163	482	396	201	5242	13.0	11.4
New market economies	1867	169	229	86	2351	10.9	13.4
Pearson $\chi^2(3)$ test (*p*-value)	17.18 (0.001)						
Contingency coefficient (*p*-value)	0.05 (0.001)						

Finding 6b: XML-based e-business frameworks are more widely used in the new market economies than EDI-based e-business frameworks ($10.9 < 13.4$). In comparison, EDI-based e-business frameworks are more widely used in the old market economies than XML-based e-business frameworks ($13.0 > 11.4$).

An empirical finding of Westarp et al. (1999) indicates that ASC X12 and EDIFACT have a significant user base in the leading capitalist countries. According to these results, the use of ASC X12 and EDIFACT has increased from the end of the 1980s so that about 35% of the 1000 largest enterprises used EDIFACT in Germany and about 45% of the 1000 largest enterprises used ASC X12 in the US in 1997. In the former socialist countries, e-business has had no room before the liberalization of the economy at the beginning of the 1990s. For this reason, the new market economies have lagged several years behind the old market economies in the use of e-business frameworks. A small user base of EDI-based e-business frameworks has made it easier to bring XML-based e-business frameworks into use in the new market economies.

Table 10: The use of EDI-based and XML-based e-business frameworks in different industries

Industries	Number of companies					% of companies	
	No EDI or XML	Only EDI	Only XML	Both EDI and XML	Total	EDI	XML
No EDI-based or XML-based industry-specific e-business frameworks	1594	158	111	71	1934	11.8	9.4
Only EDI-based industry-specific e-business frameworks	1347	160	69	28	1604	11.7	6.1
Only XML-based industry-specific e-business frameworks	1230	129	277	106	1742	13.5	22.0
Both EDI-based and XML-based industry-specific e-business frameworks	1859	204	168	82	2313	12.4	10.8
Pearson $\chi^2(9)$ test (p-value)	244.92 (0.0)						
Contingency coefficient (p-value)	0.18 (0.0)						

Finding 6c: XML-based e-business frameworks are more common than EDI-based e-business frameworks in the industries for which there exists an XML-based but no EDI-based industry-specific e-business framework (13.5 < 22.0). In other industries, EDI-based e-business frameworks are more common than XML-based e-business frameworks (11.8 > 9.4, 11.7 > 6.1, 12.4 > 10.8).

Different industries have different needs. Although a cross-industry-document e-business framework may have more potential users than an industry-specific e-business framework, the value of the e-business framework does not only depend on the number of its users. An industry-specific e-business framework enabling a larger number of business interactions among a small number of companies can be more valuable than a cross-industry-document e-business framework enabling a smaller number of business interactions among a large number of companies. This explains the importance of industry-specific e-business frameworks.

If no industry-specific e-business framework exists for the industry, EDI-based e-business frameworks are important. A theoretical finding of Farrell and Saloner (1985) can explain this strong position of EDI-based e-business frameworks in such industries. Selection of an e-business framework that matches the business partner's selection can be expected to be more difficult from a large than a small number of similar e-business frameworks. If the number of XML-based e-business frameworks is larger than the number of EDI-based e-business frameworks, the companies are more uncertain about their business partners' willingness to switch over to the same XML-based e-business framework than to stay in the same EDI-based e-business framework.

In addition to the data formats, the lock-in should apply to the e-business frameworks. EDI-based e-business frameworks are mostly older than XML-based e-business frameworks. Moreover, most of EDI-based and XML-based e-business frameworks are non-proprietary standards. As the use of XML-based e-business frameworks in companies point out, there is no lock-in to EDI-based e-business frameworks. The use of EDI-based e-business frameworks has not blocked the adoption of XML-based e-business frameworks. It is necessary to remember that all cross-industry-document and industry-specific e-business frameworks do not specify only business documents. They can specify business processes in which standardized business documents are exchanged, as publication (I) explains. Many XML-based e-business frameworks (e.g. papiNet and RosettaNet) but only few EDI-based e-business frameworks (e.g. EDIFICE) specify business processes. If standardized business processes have positive effects on the use of an e-business framework, EDI-based e-business frameworks lag behind XML-based e-business frameworks. The support of some XML-based cross-industry-process and industry-specific e-business frameworks in middleware products is considerable. In 2004, the overall market share of BEA, Fujitsu, IBM, Microsoft and Oracle was nearly 60% of the middleware products (Scannell 2005). The middleware products are very important in e-business because their purpose is to enable the interoperability of different information systems within and between companies. In 2005, all five leading middleware vendors supported BPEL and RosettaNet as well as ASC X12 and EDIFACT.

3.4 Adoption and migration in supply chain integration

3.4.1 Research approach

Publication (V) explores how organizational and technological factors explain the adoption of e-business functions and the migration from EDI-based to XML-based supply chain integration in European companies. This publication is based on an exploratory study aimed at obtaining a clearer understanding of the e-business adoption and migration in supply chain integration rather than to test prior hypotheses. A *linear regression* analysis (Greene 2003) was used to study the adoption and a *logistic regression* analysis (Menard 2002) to study the migration. The data were based on the second part of the e-Business Survey 2003 and the e-Business Survey 2005 (e-Business W@tch 2004, 2005) in the same way as in publication (IV). The analyses concentrated on two dependent variables, nine independent variables and 23 control variables. Observations with a missing value had to be removed by listwise deletion so that only complete observations were used in the statistical analyses. These exclusions left 4570 usable observations for the adoption model and 329 for the migration model.

The variable *Adoption* is a dependent variable in the adoption model but also an independent variable as a technological factor in the migration model. The binary variable *Migration* is a dependent variable in the migration model. The descriptive statistics of the dependent variables is presented in Table 11.

Table 11: The descriptive statistics of dependent variables (adoption/migration)

Dependent variable	Mean	Standard deviation	Min	Max
Adoption	0.639/1.386	1.027/1.375	0/0	5/5
Migration	/0.21	/0.41	/0	/1

- *Adoption*: "Does a company sell or purchase products online on the Internet or through other computer-mediated networks or does it use online technologies other than e-mail to collaborate with business partners in the design of new products, to forecast product demand or to manage capacity or inventory?" This variable aggregates the number of the following e-business functions in the company: online sales, purchases, product design, demand forecasting and resource management. The main e-business applications support one or more of these functions (Gunasekaran et al. 2002).

- *Migration*: "Does a company intend to replace EDI-based with XML-based e-business frameworks within the next 24 months in 2003 or the next 12 months in 2005?" This binary variable is relevant only if the company uses EDI-based e-business frameworks.

The variables *Size*, *Scope* and *Skills* are organizational factors, whereas the variables *EIS*, *EDI*, *VANEDI*, *InternetEDI*, *XML* and *Other* are technological factors. The descriptive statistics of the independent variables is presented in Table 12.

Table 12: The descriptive statistics of independent variables (adoption/migration)

Independent variable	Mean	Standard deviation	Min	Max
Size	1.321/1.963	0.745/0.788	0.0/0.0	4.0/3.9
Scope	2.23/3.99	6.398/9.369	1/1	200/85
Skills	29.54/25.69	32.251/27.728	0/0	100/100
EIS	0.355/1.0	0.701/1.024	0/0	3/3
EDI	0.1/	0.301/	0/	1/
VANEDI	/0.678	/0.468	/0	/1
InternetEDI	/0.641	/0.803	/0	/1
XML	0.09/	0.285/	0/	1/
Other	0.202/0.459	0.401/0.991	0/0	1/1

- *Size*: "How many employees does a company have in the country?" The base-10 logarithm of the number of employees can be used as a proxy for the firm size (Child 1973, Zhu et al. 2003). A logarithmic transformation is used to reduce the variance of the firm size.

- *Scope*: "How many sites does a company have in the country?" Since site means a single organizational unit at a particular address, the number of sites measures the geographical rather than operational firm scope (Child 1973, Zhu et al. 2003).

- *Skills*: "What is the percentage of employees with a college or university degree in a company?" The percentage can be used as a proxy for the skills (Bresnahan et al. 2002, Hempell 2005).

- *EIS*: “Does a company have ERP, SCM or CRM systems?” This variable aggregates the number of the following enterprise information systems in the company: ERP, CRM and SCM. These enterprise information systems play a key role in e-business (Falk 2005, Gunasekaran and Ngai 2004, Ingram et al. 2002, Laudon and Laudon 2006).

- *EDI*: “Does a company use EDI-based e-business frameworks, such as ASC X12, EDIFACT, or EANCOM, to exchange standardized data?” This binary variable is used in the adoption model.

- *VANEDI*: “Does a company use EDI-based e-business frameworks over the VANs?” This binary variable is relevant only in the migration model if the company uses EDI-based e-business frameworks.

- *InternetEDI*: “Does a company use EDI-based e-business frameworks over the Internet?” This binary variable is relevant only in the migration model if the company uses EDI-based e-business frameworks.

- *XML*: “Does a company use XML-based e-business frameworks, such as cXML, RosettaNet or UBL, to exchange standardized data?” This variable is binary.

- *Other*: “Does a company use Standard Exchange for Product Data (STEP), technical specifications agreed between the company and its business partner or any other technical standards to exchange standardized data?” This variable is binary.

Some variations can be explained only if control variables are appropriately applied. It is common to use binary variables to control the year, country and industry effects. In publication (V), one binary variable *Year* controls the year effects, 22-23 binary variables $Country_i$ the country effects and ten binary variables $Industry_j$ the industry effects. Tables 13 and 14 present the number of observations from different countries and industries taking into account the year.

The independent and control variables are often entered into the linear combination when the adoption or migration is the dependent variable in a regression model (e.g. Hong and Zhu 2006, Prosser and Nickl 1997, Zhu et al. 2003). For these reasons, the regression models are simple in publication (V). The adoption model is based on the linear regression

$$\begin{aligned} Adoption &= \alpha + \alpha_{Size} Size + \alpha_{Scope} Scope + \alpha_{Skills} Skills + \\ &\alpha_{EIS} EIS + \alpha_{EDI} EDI + \alpha_{XML} XML + \alpha_{Other} Other + \alpha_{Year} Year + \sum_{i=1}^{23} \alpha_i^C Country_i + \sum_{j=1}^{10} \alpha_j^I Industry_j + \varepsilon \end{aligned}, \quad (1)$$

where αs are coefficients and ε is an error term. The migration model relies on the logistic regression

$$\ln\left(\frac{P(Migration=1 \mid Size,..,Industry_j)}{P(Migration=0 \mid Size,..,Industry_j)}\right) = \beta + \beta_{Size}Size + \beta_{Scope}Scope + \beta_{Skills}Skills + \beta_{Adoption}Adoption + \beta_{EIS}EIS + , \quad (2)$$

$$\beta_{VANEDI}VANEDI + \beta_{InternetEDI}InternetEDI + \beta_{Other}Other + \beta_{Year}Year + \sum_{i=1}^{22}\beta_i^C Country_i + \sum_{j=1}^{10}\beta_j^I Industry_j + \varepsilon$$

where $P()$ is a conditional probability, βs are coefficients and ε is an error term. Logistic regression was chosen over linear regression because the dependent variable *Migration* follows a nominal rather than an interval scale. The control variable of Latvia was dropped from the migration model because there were no observations from Latvia.

Table 13: Observations from different countries (adoption/migration)

Country	**Observations**			**Country**	**Observations**		
	2003	**2005**	**Total**		**2003**	**2005**	**Total**
Austria	46/3	0/0	46/3	Latvia	47/0	0/0	47/0
Belgium	181/10	0/0	181/10	Lithuania	32/1	0/0	32/1
Cyprus	33/2	0/0	33/2	Netherlands	151/5	0/0	151/5
Czech Republic	49/4	245/25	294/29	Norway	56/5	0/0	56/5
Denmark	34/6	0/0	34/6	Poland	126/9	236/14	362/23
Estonia	226/2	0/0	226/2	Portugal	208/10	0/0	208/10
Finland	139/13	0/0	139/13	Slovak Republic	132/5	0/0	132/5
France	77/8	331/57	408/65	Slovenia	110/3	0/0	110/3
Germany	72/2	290/37	362/39	Spain	82/0	287/31	369/31
Greece	157/2	0/0	157/2	Sweden	219/18	0/0	219/18
Hungary	152/11	0/0	152/11	UK	68/0	223/27	291/27
Ireland	109/5	0/0	109/5	Total	2573/ 126	1997/ 203	4570/ 329
Italy	67/2	385/12	452/14				

Table 14: Observations from different industries (adoption/migration)

Industry	**Observations**			**Industry**	**Observations**		
	2003	**2005**	**Total**		**2003**	**2005**	**Total**
Food and beverages	0/0	271/40	271/40	Transport equipment	306/21	301/38	607/59
Textile, footwear and leather	291/15	257/29	548/44	Construction	49/0	274/12	323/12
Publishing and printing	0/0	226/20	226/20	Retail	341/21	0/0	341/21
Chemicals and chemical products	282/20	240/34	522/54	ICT services	271/6	169/17	440/23
Machinery and equipment	0/0	259/13	259/13	Business services	723/23	0/0	723/23
Electrical machinery and electronics	310/20	0/0	310/20	Total	2573/ 126	1997/ 203	4570/ 329

3.4.2 Adoption of e-business functions

The linear regression model (1) should be examined for multicollinearity and heteroscedasticity (Greene 2003). High multicollinearity is a problem because the relative importance of the independent variables is unreliable. This can be assessed by the variance inflation factor (VIF). If the VIF of an independent variable is larger than four or the VIF of a control is larger than ten, there is multicollinearity. The independent variable *EIS* had the largest VIF 1.439 and the control variable of Italy 5.542. This confirmed that there is no problem with high multicollinearity. Due to heteroscedasticity of the variance of the error term, ordinary least squares (OLS) estimators are unbiased and consistent but not efficient. This can affect the statistical significance of the independent variable. The White test can be applied to detect heteroscedasticity. This test has the null hypothesis that the variance of the error term is homoscedastic. Since the null hypothesis was rejected (NR^2 = 422.325, p = 0.0), this variance is heteroscedastic. Instead of OLS estimators, White estimators were used in the linear regression model. The results of the linear regression (1) are reported in Table 15.

Table 15: Adoption of e-business functions

Variable	**α-coefficient**	**Standard error**	***p*-value**
Constant	0.911	0.122	0.0
Size	-0.002	0.022	0.929
Scope	0.008	0.003	0.007
Skills	0.0004	0.0005	0.375
EIS	0.337	0.029	0.0
EDI	0.365	0.064	0.0
XML	0.477	0.072	0.0
Other	0.421	0.044	0.0

The value of R^2 0.267 indicates that the independent and control variables can explain 26.7% of the variance of the dependent variable in the linear regression model. This model fit is satisfactory. According to Table 15, all the variables related to technological factors but only the variable *Scope* related to organizational factors are statistically significant at the level 0.01 ($p < 0.01$). The significant variables lead to three findings.

Finding 7a: A company with a wider scope has more e-business functions ($\alpha_{Scope} > 0$).

Finding 7a is consistent with the positive effects of the firm scope on the adoption (Forman 2005, Zhu et al. 2003). Gurbaxani and Whang (1991) argue that the geographic scope decreases the average operating costs and increases internal coordination costs but its impacts on external coordination costs are ambiguous. E-business functions can be important in internal supply chain integration because they also reduce internal coordination costs. Although many papers stress the firm size, the variable *Size* is not statistically significant. Forman (2005) and Zhu et al. (2003) present that the firm size has a positive effect on the adoption. Hong and Zhu (2006) in turn argue that the firm size has a negative effect. Following Black and Lynch (2001), Bresnahan et al. (2002) and Hempell (2005), the skills should be positively associated with the adoption.

However, the variable *Skills* is not statistically significant. In all, the adoption of e-business functions is not limited to larger companies and companies with higher skills.

Finding 7b: A company having more enterprise information systems has more e-business functions ($\alpha_{EIS} > 0$).

Finding 7c: A company exchanging standardized data has more e-business functions ($0 < \alpha_{EDI} \leq \alpha_{Other} \leq \alpha_{XML}$).

Findings 7b and 7c support relatively well the positive effects of technology competence (Zhu et al. 2003), web functionalities and technology integration on the adoption (Hong and Zhu 2006). In fact, both enterprise information systems and exchange of standardized data play a major role in the adoption. This is consistent with the need for technological readiness that the use of EDI requires (Chwelos et al. 2001, Iacovou et al. 1995). The aggregate and each of the enterprise information systems have a significant effect. In addition, XML-based e-business frameworks, such as RosettaNet, have larger effects and EDI-based e-business frameworks, such as EDIFACT, have smaller effects on the adoption of e-business functions than other standards, such as STEP. However, the differences in these effects are not statistically significant. The Wald test did not reject the null hypothesis ($W = 1.347$, $p = 0.51$) that the restriction $\alpha_{EDI} = \alpha_{XML} = \alpha_{Other}$ holds. This does not disprove that the XML format enables more flexible or less expensive exchange of standardized data than the EDI formats (e.g. Chiu and Chen 2005, Goutsos and Karacapilidis 2004). In fact, XML-based e-business frameworks seem to support the adoption of a larger number of e-business functions than EDI-based e-business frameworks. The data can be expected to convey richer information in product design, demand forecasting and resource management functions than in sales and purchases functions. For example, the exchange of purchase orders is relatively easy, whereas information concerning engineering changes can be very complex.

The statistical analysis of the adoption leads to two implications. Firstly, companies must pay attention to their technological capability to adopt e-business functions. This capability constitutes enterprise information systems, such as ERP, and exchange of standardized data, especially XML-based e-business frameworks. Even companies that have a smaller number of employees are able to adopt e-business functions if they have sufficient technological capability. Secondly, companies that have a large number of sites at different addresses should pursue more proactively the adoption of e-business functions given the greater potential to achieve benefits from e-business functions.

3.4.3 Migration from EDI-based to XML-based e-business frameworks

The logistic regression model (2) should be examined for multicollinearity and goodness of fit (Menard 2002). The diagnostic for multicollinearity can be obtained by a linear regression model using the same dependent, independent and control variables that are used in a logistic regression model. By examining VIFs, the independent variable *VANEDI* had the largest VIF 1.723 and the control variable of France 9.455. For this reason, there was no high multicollinearity. The Hosmer-Lemeshow test can be utilized to assess the goodness of fit. This test has the null hypothesis that the logistic regression model does not predict values significantly differently from the observed values. Since the null hypothesis was not rejected ($\hat{H}$ = 3.66, p = 0.886), there is no difference between the observed and predicted values. Maximum likelihood estimators were used in the logistic regression model. The results of the logistic regression (2) are presented in Table 16.

Table 16: No migration versus migration from EDI-based to XML-based e-business frameworks.

Variable	β-coefficient	Standard error	*p*-value
Constant	-3.057	1.411	0.03
Size	0.928	0.29	0.001
Scope	0.039	0.02	0.053
Skills	0.018	0.008	0.022
Adoption	0.402	0.157	0.01
EIS	0.216	0.2	0.28
VANEDI	0.2	0.485	0.68
InternetEDI	0.465	0.448	0.299
Other	-0.298	0.406	0.463

The value of Nagelkerke R^2 0.457 does not measure the explained percent of the variance of the dependent variable but it approximates R^2 in the logistic regression model. The model fit is good. In Table 16, the variables *Size* and *Skills* associated with organizational factors and the variable *Adoption* associated with technological factors are statistically significant at the level 0.05 ($p < 0.05$). These significant variables result in three findings.

Finding 8a: A larger company is more likely to replace EDI-based with XML-based e-business frameworks ($\beta_{Size} > 0$).

Finding 8b: A company with higher skills is more likely to replace EDI-based with XML-based e-business frameworks ($\beta_{Skills} > 0$).

Finding 8a does not uphold that the firm size affects the migration negatively (Hong and Zhu 2006). This is no surprise because the use of EDI is more common in larger companies (Banerjee and Golhar 1994, Hill and Scudder 2002, Premkumar et al. 1997). Since bringing a new e-business framework into use requires investments, larger companies often have the resources to do this. In addition, the larger companies can often utilize an e-business framework to such an extent that the benefits from the new e-business framework justify the investments in external supply chain integration (Stefansson 2002). Finding 8b is consistent with Bartel and Lichtenberg (1987) who present that highly educated employees have a comparative advantage with respect to the implementation of new technologies. A possible explanation is that companies with higher skills have better learned how to bring an e-business framework into use successfully. These companies are also more willing to replace EDI-based with XML-based e-business frameworks. The variable *Scope* is not statistically significant. If internally-oriented enterprise information systems, especially ERP, reduce more internal coordination costs than e-business frameworks, e-business frameworks play a minor role in internal supply chain integration. Therefore, the firm scope should not affect the migration. In contrast to the adoption of e-business functions, larger companies and companies with higher skills are more likely to migrate from EDI-based to XML-based e-business frameworks.

Finding 8c: A company having more e-business functions is more likely to replace EDI-based with XML-based e-business frameworks ($\beta_{Adoption} > 0$).

Finding 8c confirms to some extent that web functionalities influence the migration positively (Hong and Zhu 2006). Only the number of the e-business functions adopted has a significant effect on the migration. On the one hand, some companies have experiences that XML-based e-business frameworks work so well with e-business functions that there is no reason to use both EDI-based and XML-based e-business frameworks. The update and use of multiple e-business frameworks is more costly, especially if these e-business frameworks are based on different data formats. On the other hand, some companies have strong expectations that XML-based e-business frameworks will support e-business functions much better than EDI-based e-business frameworks. The variables *EIS*, *VANEDI*, *InternetEDI* and *Other* are not statistically significant. This contradicts the findings that externally-oriented enterprise information systems, such as SCM and CRM, are positively (Hong and Zhu 2006) and VAN usage is negatively related to the migration (Hong and Zhu 2006, Zhu et al. 2006). The use of enterprise information systems is independent on the use of a particular e-business framework. In addition, other standards or EDI-based e-business frameworks over the VANs do not significantly slow down the migration to XML-based e-business frameworks. The Internet gives globally available immediate access independent of place and time and lowers the information processing and communication costs (Manecke and Schoensleben, 2004) However, EDI-based e-business frameworks over the Internet do not speed up the migration.

The statistical analysis of the migration provides two implications. Firstly, companies need to assess the appropriateness of the migration from EDI-based to XML-based e-business frameworks to certain organizational characteristics, such as a large number of employees or highly educated employees, as suggested by findings. Secondly, companies that have adopted a large number of e-business functions should migrate from EDI-based to XML-based e-business frameworks. VAN usage does not inhibit the migration.

4 Discussion

This section discusses the significance of the results of the thesis. Subsection 4.1 assesses the validity and reliability of these results and subsection 4.2 compares them with the results presented in the previous research. Finally, subsection 4.3 proposes topics for further research.

4.1 Validity and reliability

Although most of the results of the thesis have been published in international peer-reviewed journals, it is necessary to assess their validity and reliability. The assessment concentrates on matters that have improved the validity and reliability of the results and on possible limitations of the results. This assessment is presented first in general and then publication by publication.

Good research relies on validity and reliability. A research method is said to be valid if it actually measures what it is supposed to measure. Reliability is concerned with the extent to which a research method is able to produce the same data when measured at different times or by different researchers, assuming that the phenomena being measured has not actually changed. Triangulation strengthens a study by combining several kinds of methods. Triangulation may include multiple research methods of data collection and data analysis. The research methods chosen in the triangulation to test the validity and reliability of a study depend on the criteria of the research. Since triangulation helps to control biases and avoid limitations of a particular research method, it improves confirmation and generalization of a study. This thesis combines several research methods. A literature study was used in publication (I), design science research in publication (II) and a comparative analysis in publication (III) to answer the question of how XML and e-business frameworks support supply chain integration. Case study research was utilized in publication (II), a comparative analysis in publication (IV) and statistical analyses in publications (IV) and (V) to find an answer to the question of what kind of a role XML-based e-business frameworks play in supply chain integration compared to EDI-based e-business frameworks.

Since data formats, e-business frameworks, integration systems and papers on them are artifacts made by humans, their research is not straightforward. For example, the current integrations systems are different from those of two decades ago and the integration systems after two decades will be more or less different from the current ones. The considerable speed of change is also a major challenge. Understanding data formats and e-business frameworks requires continuous follow-up because changes happen quickly as the technologies and organizations evolve. Many new technologies have been released over the past few years and new versions of some technologies emerge almost on a monthly basis. A notable change is the use of XSD instead of DTD in validation. Moreover, old e-business frameworks have disappeared and new ones have emerged. For example, BizTalk Framework was officially closed in 2002 and eCo has been inactive for years, whereas the first full version of UBL was published in 2004. These facts should be kept in mind when evaluating the validity and reliability of the results.

1. Publication (I) covered a large number of XML-based e-business frameworks. Experiences from XML-based supply chain integration were also sought from multiple sources. Publication (I) is limited in two ways. Its focus was directed on e-business frameworks that support industrial procurement, design, production or distribution. Furthermore, security and reliability aspects of supply chain integration were not studied in detail.

2. For publication (II), three versions of the CA were implemented and evaluated within the industrial case. The preliminary versions of the CA were presented at international conferences (Seilonen et al. 2001, Nurmilaakso et al. 2001). Instead of using a commercial integration system, an integration system prototype was developed and used to get an understanding of XML, XML technologies and XML-based e-business frameworks in supply chain integration. Evaluation of the CA was carried out to a large extent by researchers not involved in its design or implementation. This was sensible for two reasons. On the one hand, developers of the CA had no sufficient expertise to perform its evaluation. On the other hand, it was necessary to minimize the potential bias resulting from the expertise of the CA. The evaluation was based on experiments with the CA as well as interviews in the case companies. In addition to the evaluators, the case companies' representatives as well as the developers of the CA reviewed the evaluation results. However, publication (II) has four limitations. Firstly, a small number of business interactions with the CA were evaluated within a single industrial case. Secondly, the CA was never connected to operative information systems at ABB and never installed at InCap. Therefore, only semi-automated business interactions were evaluated within the industrial case. Thirdly, the CA was implemented over the Internet, whereas the EDI-based integration system was used over the VAN. Fourthly, the CA did not support a large number of functionalities and some important properties related to security and reliability.

3. For publication (III), the preliminary results were presented in an international workshop (Kotinurmi et al. 2003). The feedback pointed out that the variables identified for the analysis of XML-based e-business frameworks and their standardization are incontestable but the identification and assignment of their values cannot be completely unambiguous. Publication (III) is limited in two ways. An analysis of e-business frameworks and their standardization focused on a small number of e-business frameworks supporting industrial procurement, design, production or distribution. In addition, the results of this analysis were based on analytical generalizations about instances. Although these instances admit subsequent reinterpretations, they do not produce statistical generalizations.

4. Publication (IV) studied the use of data formats and e-business frameworks with a large number of e-business frameworks and companies. This publication has four limitations. The data on the use of data formats did not cover all possibly important EDI-based and XML-based e-business frameworks. The data on the use of e-business frameworks were self-reported, which can cause reporting errors and

sample biases. It is unavoidable in telephone interviews that there is no ideal respondent. The general manager may not always be aware of the technical implementations and the small company familiar with the technical terms. However, a large survey sample reduces the effect of errors and biases. In addition, the data on the use of e-business frameworks did not contain observations from some important countries, such as the US, and industries, such as financial services. This may limit the generalizability. It was also not possible to evaluate perfectly the changes in the use of e-business frameworks. This would require the data on the same companies over several years.

5. Publication (V) analyzed the adoption and migration in a large number of companies. This publication is limited in four ways. As in publication (IV), the data were self-reported but a large survey sample mitigates the effect of reporting errors and sample biases. In addition, the data did not cover some important countries and industries. Due to the nature of the data, some important organizational and technological factors were ignored. This is one reason why regression models were simple. The chosen factors are not latent but they measure organizations and technologies at the general level. Finally, the regression models do not reveal causal relationships but statistical associations.

4.2 Comparison with previous research

4.2.1 How do XML and e-business frameworks support supply chain integration?

Compared to EDI-based supply chain integration, there is not much experience from XML-based supply chain integration, as publication (I) clearly states. Considering how much effort has been devoted to developing XML technologies and e-business frameworks, it is amazing how few experiences have been properly reported from the XML-based integration system prototypes and operative integration systems, especially their benefits and costs. Except for Chiu and Chen (2005), none of the reported studies cover both the technical and business aspects of XML-based supply chain integration, which is one purpose of publication (II). A number of studies on the prototypes (e.g. Buxmann et al. 2002, Chiu and Chen 2005, Kotinurmi et al. 2004, Lu et al. 2001, Tikkala et al. 2005) and case studies on the operative integration systems (e.g. Auramo et al. 2005, Lu et al. 2006, RosettaNet 2002a, Yen et al. 2004) point out that XML and basic XML technologies work in supply chain integration. The first impression may be that XML is much ado about nothing. The context-free languages can be scanned and parsed using well-known open-source tools, such as Lex and Yacc (Aho et al. 1986). Transformations with XSLT and simple validations with DTD and XSD are easier because less programming is required. Of course, these technologies also suffer from some deficiencies (e.g. Kotinurmi et al. 2004, Tikkala et al. 2005). However, the fact is that basic XML technologies enable the exchange of business documents as XML documents between the business partners' information systems. In addition, XML provides means for describing business processes, as publication (I) argues, or it can be used to configure "technical" processes for business interactions, as publication (II) demonstrates. Publication (II) also points out that XML-based semi-automated business interactions can be useful. This kind of a solution can work with the companies having an insufficient IT infrastructure (Yen et al. 2004).

There are two interesting papers considering the division of labor between the data formats and e-business frameworks. Hasselbring and Weigand (2001) make a difference between the standardization at the lexical, syntactic and semantic level. This view concurs with publication (I). Data formats, such as XML, are necessary standards in syntactic interpretations but insufficient in semantic interpretations. Medjahed et al. (2003) present that the B2B interaction standards deal with communication, content and business process layers. There are clear similarities between the simultaneous work of Medjahed et al. (2003) and publications (I) and (III). The content layer corresponds to the business document issues, the business process layer to the business process issues and the communication layer in the B2B interaction standards to the messaging issues in the e-business frameworks. Four papers (Chari and Seshadri 2004, Medjahed et al. 2003, Nelson et al. 2005, Shim et al. 2000) seem to compare the basic properties of XML-based e-business frameworks. All of these papers deal with business document issues, three papers with business process issues and three papers with messaging issues. Shim et al. (2000) as well as Chari and Seshadri (2004) also take into account industry domain specificity. Compared to these papers, publications (I) and (III) cover a larger number of XML-based e-business frameworks.

According to publication (III), there are commonalities and regularities related to the properties and standardization of XML-based e-business frameworks. All e-business frameworks are limitedly open so that they cannot be modified or extended in proprietary directions. This commonality is supported by the simultaneous work of Nelson et al. (2005), which suggests that the standardization of XML-based industry-specific e-business frameworks is based on free provision of standards. Most XML-based e-business frameworks are standardized in formal organizations that can be regarded as committees. This commonality matches well with the theoretical findings presented in the literature (Farrell and Saloner 1988, Shapiro and Varian 1999). Chari and Seshadri (2004) argue that most of XML-based industry-specific e-business frameworks are consortia-based standards. The negative reactions of financial markets to non-proprietary standardization (Aggarwal et al. 2006) may explain why companies participate in standardization of e-business frameworks indirectly through committees rather than directly through markets. In addition, there are two regularities. Industry-specific e-business frameworks seem to be more comprehensive in their properties than cross-industry e-business frameworks. Vendors tend to drive the standardization of cross-industry e-business frameworks, whereas users tend to drive the standardization of industry-specific e-business frameworks. These regularities differ from the findings presented in the literature (e.g. Shapiro and Varian 1999). Firstly, supply chain integration depends on the volume, diversity, breadth and depth of the business interactions (Massetti and Zmud 1996). Secondly, the users have an important role in the standardization of e-business frameworks, although the vendors have traditionally dominated the standardization (Jakobs 2002).

4.2.2 Compared to EDI-based e-business frameworks, what kind of a role do XML-based e-business frameworks play in supply chain integration?

Many papers (e.g. Hsieh and Lin 2004, Gosain et al. 2003, Kanakamedala et al. 2003, Power 2005, Reimers 2001, Wareham et al. 2005) deal with questions about the advantages and disadvantages of EDI and XML. Their answers are more or less ambiguous. Empirical evidence is also quite limited. The literature seems to contain no paper which compares the use of EDI and XML formats in e-business frameworks or analyzes the use or impacts of EDI-based and XML-based e-business frameworks statistically. Since the comparison between EDI and XML is not straightforward, the thesis studies the advantages and disadvantages of EDI and XML from the case-specific and generic viewpoints. Publication (II) stresses the case-specific viewpoint and publications (IV) and (V) concentrate on the generic viewpoint. Publication (V) also analyzes the factors affecting the migration from EDI-based to XML-based e-business frameworks statistically.

Publication (II) demonstrates the CA that was able to exchange purchase order, purchase order response and invoice documents as xCBL documents and order list and demand forecast documents as XML documents over the Internet successfully, whereas EDIFACT messages did not support the exchange of order list and demand forecast documents in the industrial case. Since XML enables customized business documents and the CA used the Internet instead of the VANs, the CA was more flexible to implement and operate than EDI-based integration systems. Preliminary results concerning XML-based supply chain integration show that within the industrial case the use of the CA can provide cost savings in comparison to EDI-based supply chain integration. Both implementation and operating costs seem to be lower for XML-based than for EDI-based integration systems. This case-specific evidence is consistent with four studies (Chiu and Chen 2005, Olson and Williams 2001, RosettaNet 2001, 2002b). These studies point out that XML-based supply chain integration using RosettaNet can provide flexibility and cost savings compared to EDI-based supply chain integration. Compared to the prototype of Chiu and Chen (2005), the CA enables the use of HTTP in addition to SMTP but does not support S/MIME. However, it is not completely clear in the industrial case to what extent the flexibility and inexpensiveness are dependent on the XML format and to what extent on the Internet, although publication (II) takes a stand to both the technical and business aspects of XML-based supply chain integration.

Publication (IV) proves that SDOs have replaced the ASC X12 and EDIFACT formats with the XML format in many industry-specific e-business frameworks. The use of XML-based e-business frameworks has increased more than the use of EDI-based e-business frameworks and the use of XML-based e-business frameworks is more common in the new market economies than in the old market economies. This generic evidence challenges well-known findings presented in the economics of standards. Based on a theoretical finding of Katz and Shapiro (1986) and an empirical finding of David (1985), SDOs should be locked into the ASC X12 and EDIFACT formats in their e-business frameworks and companies should be locked into EDI-based e-business frameworks in general. Since this is not true, publication (IV) upholds to some extent the critical arguments of Liebowitz and Margolis (1990, 1995). Publication (IV) also finds out that the existence of industry-specific e-business frameworks affects the use of e-business frameworks in different industries. Since the number of XML-based cross-industry e-business frameworks is larger than the number of EDI-based cross-industry e-business frameworks, the companies are more uncertain about their business partners' willingness to switch over to the same XML-based e-business framework than to stay in the same EDI-based e-business framework. This is supported by a theoretical finding of Farrell and Saloner (1985).

Publication (V) studies the impacts of EDI-based and XML-based e-business frameworks on the adoption of e-business functions and the migration from EDI-based to XML-based e-business frameworks in supply chain integration. Forman (2005), Hong and Zhu (2006) and Zhu et al. (2003) analyze the adoption and Hong and Zhu (2006) and Zhu et al. (2006) study the migration in e-business but these papers do not take into account XML-based e-business frameworks. In contrast to Zhu et al. (2003), even smaller companies adopt e-business functions if they have sufficient technological capability. XML-based e-business frameworks seem play a more important role than EDI-based e-business frameworks. Certain organizational characteristics, such as firm size, have positive effects on the migration from EDI-based to XML-based e-business frameworks. In contrast to Zhu et al. (2006), the VAN usage does not weaken the companies' intentions to migrate. Especially, companies that have adopted a large number of e-business functions are willing to abandon EDI-based e-business frameworks.

4.3 Further research

For further research, there are four important topics. Firstly, there is no need to develop integration system prototypes to evaluate the basic XML technologies. Since there are high hopes that Web Services and Semantic Web technologies will facilitate supply chain integration (Ding et al. 2002, Staab et al. 2003), it is important to test and report experiences from SOAP, UDDI, Web Services Definition Language (WSDL), Resource Description Framework (RDF), RDS Schema (RDFS) and Web Ontology Language (OWL) in the integration systems. How they support supply chain integration?

Secondly, in what kinds of situations supply chain integration with e-business frameworks is most desirable. The challenge is identify the most critical business processes and the most effective attributes. For example, RosettaNet studies (RosettaNet 2002b, RosettaNet Japan 2003) indicate that forecasting and order management are such business processes in the electronics industry. Malone et al. (1987) emphasize the role of ICT in situations characterized by asset specificity and product complexity.

Thirdly, there is available information on the properties of e-business frameworks. However, more information on the standardization of e-business frameworks is necessary. This can be achieved by a longitudinal analysis of a large number of e-business frameworks.

Finally, a multiple case study can shed light to the technological, organizational and economic factors affecting the benefits and costs of EDI-based and XML-based supply chain integration. This study should include companies that have utilized only EDI-based e-business frameworks, only XML-based e-business frameworks and both EDI-based and XML-based e-business frameworks as well as companies that have replaced EDI-based with XML-based e-business frameworks. On the other hand, a statistical analysis of EDI-based and XML-based supply chain integration can also provide valuable results. Following the idea of Massetti and Zmud (1996), this analysis requires data on the diversity, breadth and depth of EDI-based and XML-based supply chain integration in different industries (e.g. financial services) and countries (e.g. the US) over several years.

5 Conclusions

In the 1990s, the Internet, Java and XML opened up new possibilities of utilizing ICTs in business. These possibilities are also related to supply chain integration, which requires information sharing between business partners. If the business partners have different kinds of business documents, business processes or information systems, it is difficult to exchange the business documents in the business processes efficiently. The business partners must have a shared understanding of their ways of doing business before their information systems can be interoperable. The business partners have to know what information they should share, when and how. This thesis aims to enhance knowledge of the XML format, e-business frameworks and supply chain integration by answering two research questions.

How do XML and e-business frameworks support supply chain integration? Supply chain integration, especially exchange of business documents in business processes, would be straightforward if all organizations understood the meanings for terms and modes of operations similarly and had similar information systems in the supply chain. The differences are costly but standardization can bring order into complexity and uncertainty by reducing the variety. Data formats, such as ASC X12, EDIFACT and XML, define data structures and data elements in general. Since business partners must know what information should be shared when and how, the data formats are necessary in syntactic interpretations but insufficient in semantic interpretations. Therefore, e-business frameworks are needed in information sharing within and between companies. The e-business framework limits the syntax but extends the semantics of the data format in the business context. XML-based e-business frameworks can specify business documents as well as business processes and messaging.

An XML-based integration system prototype called CA supports the claim that XML and basic XML technologies are very useful tools in supply chain integration. The CA was designed and implemented using Java, DTD and XSLT and tested at ABB Control and InCap Electronics. It was used in an industrial case for studying the properties of XML-based integration systems from both the development and usage perspectives. Within this industrial case, the CA fulfilled the functional requirements of supply chain integration. The CA was also flexible to implement and use. Instead of the VAN, the CA worked over the Internet. xCBL, an XML-based e-business framework, provided basic business documents and XML enabled customized business documents that can be validated by DTD and transformed by XSLT. In addition, the engine-processor architecture together with XML-based configuration languages facilitated the maintenance of the CA.

An analysis of 12 prominent XML-based e-business frameworks and their standardization points out that these e-business frameworks are limitedly open and have been mostly standardized in formal organizations. In addition, industry-specific e-business frameworks seem to be more comprehensive in their properties than cross-industry e-business frameworks. Software vendors prefer the standardization of cross-industry e-business frameworks, whereas users favor the standardization of industry-specific e-business frameworks. Software vendors seem to emphasize wider use and users seem to stress deeper use.

Compared to EDI-based e-business frameworks, what kind of a role do XML-based e-business frameworks play in supply chain integration? EDI-based and XML-based supply chain integration in the industrial case revealed that the business benefits of the CA were highly case-specific but its use can provide cost savings in comparison to EDI-based integration systems. A new message type with EDIFACT was three to four times more expensive to implement than a new kind of a business document with xCBL. Therefore, the implementation costs seemed to be lower for XML-based than EDI-based supply chain integration. When charges for the VAN were compared to those for the Internet, the operating costs also seemed to be lower for XML-based than EDI-based supply chain integration. However, it was not completely clear to what extent these cost savings were attributable to the properties of the CA or, for example, how the VAN operators price their services.

Based on 38 e-business frameworks, the ASC X12 and EDIFACT formats have retained a strong position in cross-industry-document e-business frameworks but the XML format has gained a significant footing in industry-specific e-business frameworks and dominates in cross-industry-process e-business frameworks. The use of EDI-based and XML-based cross-industry-document and industry-specific e-business frameworks in 7593 European companies points out that the use of XML-based e-business frameworks has increased more than EDI-based e-business frameworks in 2004. The use of XML-based e-business frameworks has become more common in the new market economies, whereas the use of EDI-based e-business frameworks has remained more common in the old market economies. In addition, XML-based e-business frameworks are more widely used than EDI-based e-business frameworks in the industries for which there is an XML-based but no EDI-based industry-specific e-business framework. In the other industries, the situation is the opposite.

The adoption of e-business functions in 4570 European companies and the migration from EDI-based to XML-based supply chain integration in 329 European companies imply that technological factors are important in the adoption and organizational factors in the migration. Not only companies with a large number of employees or highly educated employees adopt e-business functions, although they are more willing to migrate from EDI-based to XML-based e-business frameworks. XML-based e-business frameworks seem to promote the adoption of e-business functions more than EDI-based e-business frameworks. In addition, if a company uses an EDI-based e-business framework over the VANs, this does not affect its intension to switch over to an XML-based e-business framework. However, if the company has adopted a larger number of e-business functions, it will more likely abandon EDI-based e-business frameworks.

In summary, XML and basic XML technologies, together with e-business frameworks, provide a sound basis for supply chain integration. Both cross-industry and industry-specific e-business frameworks are important in supply chain integration. It is good to remember that the properties of the e-business framework depend on the participants in its standardization. Although the ASC X12 and EDIFACT formats are older non-proprietary standards than the XML format, there is no significant lock-in to the EDI formats in e-business frameworks. Moreover, companies are not locked into EDI-based e-business frameworks in general. In the short run, the XML and EDI formats are more likely complements than substitutes. Companies will not abandon EDI in some industries and countries until the uncertainty about XML is dispelled. However, XML-based supply chain integration will be a superior alternative to EDI-based supply chain integration in the long run. Firstly, XML-based e-business frameworks are often global, whereas ASC X12-based e-business frameworks are indented for North America and EDIFACT-based e-business frameworks for Europe. Secondly, EDI-based industry-specific e-business frameworks are mostly modified subsets of ASC X12 and EDIFACT. Thirdly, most of XML-based e-business frameworks specify both business documents and business processes. Fourthly, XML-based e-business frameworks seem to support a larger number of e-business functions than EDI-based e-business frameworks. XML alone does not remove all the integration problems. XML-based e-business frameworks can promote the achievement of a shared understanding that is needed in supply chain integration.

References

Aggarwal, N., Dai, Q., Walden, E.A., 2006, "Do markets prefer open or proprietary standards for XML standardization? An event study", *International Journal of Electronic Commerce*, Vol. 11, No. 1, pp. 117-136.

Aho, A., Sethi, R., Ullman, J., 1986, *Compilers: Principles, Techniques, and Tools*, Addison-Wesley, Reading, MA.

Anandarajan, A, Wen, H.J., 1999, "Evaluation of information technology investment", *Management Decision*, Vol. 37, No. 4, pp. 329-337.

Angeles, R., 2000, "Revisiting the role of Internet-EDI in the current electronic commerce scene", *Logistics Information Management*, Vol. 13, No. 1-2, pp. 45-57.

ANSI, 2005, *Accredited Standards Committee X12*, http://www.x12.org

API, 2004, *Petroleum Industry Data Exchange*, http://committees.api.org/business/pidx/index.html

Ariba, 2004, *Commerce XML*, http://www.cxml.org

Arthur, W.B., 1989, "Competing technologies, increasing returns, and lock-in by historical events", *Economic Journal*, Vol. 99, No. 394, pp. 116-131.

Auramo, J., Kauremaa, J., Tanskanen, K., 2005, "Benefits of IT in supply chain management: an explorative study of progressive companies", *International Journal of Physical Distribution & Logistics Management*, Vol. 35, No. 2, pp. 82-100.

Bagchi, P.K., Chun, B., Skjoett-Larsen, T., Soerensen, L.B., 2005, "Supply chain integration: a European survey", *International Journal of Logistics Management*, Vol. 16, No. 2, pp. 275-294.

Banerjee, S., Golhar, D.Y., 1994, "Electronic data interchange: characteristics of users and nonusers", *Information & Management*, Vol. 26, No. 1, pp. 65-74.

Bartel, A.P., Lichtenberg, F.R., 1987, "The comparative advantage of educated workers in implementing new technology", *Review of Economics and Statistics*, Vol. 69, No. 1, pp. 1-11

Bergeron, F., Raymond, L., 1997, "Managing EDI for corporate advantage: a longitudinal study", *Information & Management*, Vol. 31, No. 6, pp. 319-333.

Black, S.E., Lynch, L.M., 2001, "How to compete: the impact of workplace practices and information technology on productivity", *Review of Economics and Statistics*, Vol. 83, No. 3, pp. 434-445.

Bresnahan, T.F., Brynjolfsson, E., Hitt, L., 2002, "Information technology, workplace organization, and the demand for skilled labor: firm-level evidence", *Quarterly Journal of Economics*, Vol. 117, No. 1, pp. 339-376.

Brynjolfsson, E., Hitt, L.M., 2000, "Beyond computation: information technology, organizational transformation and business performance", *Journal of Economic Perspectives*, Vol. 14, No. 4, pp.23-48.

BPMI, 2004, *Business Process Modeling Language*, http://www.bpmi.org

Buxmann, P., Díaz, L., Wünstner, E., 2002, "XML-based supply chain management: as SIMPLEX as it is", in *Proceedings of the 35th Annual Hawaii International Conference on System Sciences*, Vol. 7, HICSS 02, January 7-10, Big Island, HI, pp. 2141-2150.

Carr, A.S., Smeltzer, L.R., 2002, "The relationship between information technology use and buyer-supplier relationships: an exploratory analysis of the buying firm's perspective", *IEEE Transactions on Engineering Management*, Vol. 49, No. 3, pp. 293-304.

Carter, J.R., Fredendall, L.D., 1990, "The dollars and sense of electronic data interchange", *Production and Inventory Management Journal*, Vol. 31, No. 2, pp. 22-25.

Chan, S., Dillon, T., Siu, A., 2002, "Applying a mediator architecture employing XML to retailing inventory control", *Journal of Systems and Software*, Vol. 60, No. 3, pp. 239-248.

Chari, K., Seshadri, S., 2004, "Demystifying integration", *Communications of the ACM*, Vol. 47, No. 7, pp. 59-63.

Child, J., 1973, "Predicting and understanding organization structure", *Administrative Science Quarterly*, Vol.18, No. 2, pp. 168-185.

Chiu, R.K., Chen, J.C.H., 2005, "A generic service model for secure data interchange", *Industrial Management & Data Systems*, Vol. 105, No. 5, pp. 662-681.

Choi, B., Raghu, T.S., Vince, A., 2004, "Addressing a standards creation process: a focus on ebXML", *International Journal of Human-Computer Studies*, Vol. 61, No. 5, pp. 627-648.

Chwelos, P., Benbasat, I., Dexter, A.S., 2001, "Empirical test of an EDI adoption model", *Information Systems Research*, Vol. 12, No. 3, pp. 304-321.

CIDX, 2004, *Chemical Industry Data Exchange*, http://www.cidx.org

Clark, T.H., Stoddard, D.B., 1996, "Interorganizational business process redesign: merging technological and process innovation", *Journal of Management Information Systems*, Vol. 13, No. 2, pp. 9-28.

Commerce One, 2004, *XML Common Business Library*, http://www.xcbl.org

Cooper, M.C., Lambert, D.M., Pagh, J.D., 1997, "Supply chain management: more than a new name for logistics", *International Journal of Logistics Management*, Vol. 8, No. 1, pp. 1-14.

Damodaran, S., 2004, "B2B integration over the Internet with XML: RosettaNet successes and challenges", in *Proceedings of the 13th International World Wide Web Conference*, May 17-22, New York, NY, pp.188-195.

David, P.A., 1985, "Clio and the economics of QWERTY", *American Economic Review*, Vol. 75, No. 2, pp. 332-337.

Ding, Y., Fensel, D., Klein, M., Omelayenko, B., 2002, "The Semantic Web: yet another hip?", *Data & Knowledge Engineering*, Vol. 41, No. 2-3, pp. 205-227.

Dogac, A., Tambag, Y., Pembecioglu, P., Pektas, S., Laleci, G., Kurt, G., Toprak, S., Kabak, Y, 2002, "An ebXML infrastructure implementation through UDDI registries and RosettaNet PIPs", in *Proceedings of the 2002 ACM SIGMOD International Conference on Management of Data*, June 3-6, Madison, WI, pp. 512-523.

e-Business W@tch, 2004, *The European E-business Report 2004 Edition: A Portrait of E-business in 10 Sectors of the EU Economy*, http://www.ebusiness-watch.org

e-Business W@tch, 2005, *The European E-business Report 2005 Edition: A Portrait of E-business in 10 Sectors of the EU Economy*, http://www.ebusiness-watch.org

Economist, 2001, "Survey: battle of the platforms", *Economist*, April 14.

Elgarah, W., Falaleeva, N., Saunders, C., Illie, V., Shim, J.T., Courtney, J.F., 2005, "Data exchange in interorganizational relationships: review through multiple conceptual lenses", *Data Base for Advances in Information Systems*, Vol. 36, No. 1, pp. 8-29.

Emmelhainz, M.A., 1990, *Electronic Data Interchange: A Total Management Guide*, Van Nostrand Reinhold, New York, NY.

Falk, M., 2005, "ICT-linked firm reorganisation and productivity gains", *Technovation*, Vol. 25, No. 11, pp. 1229-1250.

Farrell, J., Saloner, G., 1985, "Standardization, compatibility, and innovation", *RAND Journal of Economics*, Vol. 16, No.1, pp. 70-83.

Farrell, J., Saloner, G., 1988, "Coordination through committees and markets", *RAND Journal of Economics*, Vol. 19, No. 2, pp. 235-252.

Forman, C., 2005, "The corporate digital divide: determinants of Internet adoption", *Management Science*, Vol. 51, No. 4, pp. 641-654.

Frohlich, M., Westbrook, R., 2002, "Demand chain management in manufacturing and services: web-based integration, drivers and performance", *Journal of Operations Management*, Vol. 20, No. 6, pp. 729-745.

Fürst, K., Schmidt, T., 2001, "Turbulent markets need flexible supply chain communication", *Production Planning & Control*, Vol. 12, No. 5, pp. 525-533.

Goldfarb, C.F., Prescod, P., 2003, *Charles F. Goldfarb's XML Handbook*, Prentice-Hall, Upper Saddle River, NJ.

Goodhue, D.L., Wybo, M.D., Kirsch, L.J., 1992, "The impact of data integration on the costs and benefits of information systems", *MIS Quarterly*, Vol. 16, No. 3, pp. 293-311.

Gosain, S., Malhotra, A., El Sawy, O.A., Chehade, F., 2003, "The impact of common e-business interfaces", *Communications of the ACM*, Vol. 46, No. 12, pp. 186-195.

Goutsos, S., Karacapilidis, N. 2004, "Enhanced supply chain management for e-business transactions", *International Journal of Production Economics*, Vol. 89, No. 2, pp. 141-152.

Greene, W.H., 2003, *Econometric Analysis*, Prentice-Hall, Upper Saddle River, NJ.

Gulledge, T., 2006, "What is integration?", *Industrial Management & Data Systems*, Vol. 106, No. 1, pp. 5-20.

Gunasekaran, A., Marri, H.B., McGaughey, R.E., Nebhwani, M.D., 2002, "E-commerce and its impact on operations management", *International Journal of Production Economics*, Vol. 75, No. 1-2, pp. 185-197.

Gunasekaran, A., Ngai, E.W.T., 2004, "Information systems in supply chain integration and management", *European Journal of Operational Research*, Vol. 159, No. 2, pp. 269-295.

Gurbaxani, V., Whang, S., 1991, "The impact of information systems on organizations and markets", *Communications of the ACM*, Vol. 34, No. 1, pp. 59-73.

Hasselbring, W., 2000, "Information system integration", *Communications of the ACM*, Vol. 43, No. 6, pp. 32-36.

Hasselbring, W., Weigand, H., 2001, "Languages for electronic business communication: state of the art", *Industrial Management & Data Systems*, Vol. 101, No. 5, pp. 207-216.

Hayes, F., 2002, "The story so far: e-commerce", *ComputerWorld*, June 17.

Hempell, T., 2005, "Does experience matter? Innovations and the productivity of information and communication technologies in German services", *Economics of Innovation and New Technology*, Vol. 14, No. 4, pp. 277-303.

Hill, C.A., Scudder, G.D., 2002, "The use of electronic data interchange for supply chain coordination in the food industry", *Journal of Operations Management*, Vol. 20, No. 4, pp. 375-387.

Hong, W., Zhu, K., 2006, "Migrating to internet-based e-commerce: factors affecting e-commerce adoption and migration at the firm level", *Information & Management*, Vol. 43, No. 2, pp. 204-221.

Hsieh, C.T., Lin, B., 2004, "Impact of standardization on EDI in B2B development", *Industrial Management & Data Systems*, Vol. 104, No. 1, pp. 68-77.

Iacovou, C.L., Benbasat, I., Dexter, A.S., 1995, "Electronic data interchange and small organizations: adoption and impact of technology", *MIS Quarterly*, Vol. 19, No. 4, pp. 465-485.

Ingram, T.N., LaForge, R.W., Leigh, T.W., 2002, "Selling in the new millennium: a joint agenda", *Industrial Marketing Management*, Vol. 31, No. 7, pp. 559-567.

Intel, 2004, *Automating with RosettaNet: An Intel Case Study of Order-to-payment Automation in the Asia Pacific Region*, http://www.rosettanet.org

Iskandar, B.Y., Kurokawa, S., LeBlanc, L.J., 2001, "Adoption of electronic data interchange: the role of buyer-supplier relationships", *IEEE Transactions on Engineering Management*, Vol. 48, No. 4, pp. 505-517.

Jakobs, K., 2002, "A proposal for an alternative standards setting process", *IEEE Communications Magazine*, Vol. 40, No. 7, pp. 118-123.

Jakobs, K., Procter, R., Williams, R., 1998, "User participation in standards setting - the panacea?", *ACM Standard View*, Vol. 6, No. 2, pp. 85-89.

Jansson, K., Karvonen, I., Mattila, V.P., Nurmilaakso, J., Ollus, M., Salkari, I., Ali-Yrkkö, J., Ylä-Anttila, P., 2001, *Uuden tietotekniikan vaikutukset liiketoimintaan* (*Impacts of Modern Information Technology on Business*), Teknologiakatsaus 111, National Technology Agency of Finland, Helsinki, Finland.

Jiménez-Martínez, J., Polo-Redondo, Y., 2004, "The influence of EDI adoption over its perceived benefits", *Technovation*, Vol. 24, No. 1, pp. 73-79.

Jones, R., 2001, "B2B integration", *Manufacturing Engineer*, Vol. 80, No. 4, pp. 165-168.

Kaefer, F., Bendoly, E., 2004, "Measuring the impact of organizational constraints on the success of business-to-business e-commerce efforts: a transactional focus", *Information & Management*, Vol. 41, No. 5, pp. 529-541.

Kanakamedala, K., King, J., Ramsdell, G., 2003, "The truth about XML", *McKinsey Quarterly*, No. 3, pp. 9-12.

Katz, M.L., Shapiro, C., 1985, "Network externalities, competition, and compatibility", *American Economic Review*, Vol. 75, No. 3, pp. 424-440.

Katz, M.L., Shapiro, C., 1986, "Technology adoption in the presence of network externalities", *Journal of Political Economy*, Vol. 94, No. 4, pp. 822-841.

Kauffman, R.J. Walden, E.A., 2001, "Economics and electronic commerce: survey and directions for research", *International Journal of Electronic Commerce*, Vol. 5, No. 4, pp. 5-116.

Kotinurmi, P., Laesvuori, H., Jokinen, K., Soininen, T., 2004, "Integrating design document management systems using the RosettaNet e-business framework", in *Proceedings of the 6th International Conference on Enterprise Information Systems*, Vol. 4, ICEIS 2004, April 14-17, Porto, Portugal, pp. 502-509.

Kotinurmi, P., Nurmilaakso, J.M., Laesvuori, H., 2003, "Standardization of XML-based e-business frameworks", in King, J.L., Lyytinen, K. (Eds.), *Proceedings of the Workshop on Standard Making: A Critical Research Frontier for Information Systems*, ICIS 2003 Pre-conference Workshop, December 12-14, Seattle, WA, pp. 135-146.

Kuan, K.K.Y., Chau, P.Y.K., 2001, "A perception-based model for EDI adoption in small businesses using a technology-organization-environment framework", *Information & Management*, Vol. 38, No. 8, pp. 507-521.

Kärkkäinen, S., Maunuksela-Malinen, P., Saloranta, A., 2001, *Yritysten välinen sähköinen liiketoiminta. EDI/OVT:n käyttö Suomessa* (*Business-to-business E-commerce. The Use of EDI in Finland*), Julkaisusarjan osa 4, Finnish Information Society Development Center, Helsinki, Finland.

Lambert, D.M., Cooper, M.C., Pagh, J.D., 1998, "Supply chain management: implementation issues and research opportunities", *International Journal of Logistics Management*, Vol. 9, No. 2, pp. 1-19.

Laudon, J.P., Laudon, K.C., 2006, *Essentials of Business Information Systems*, Prentice-Hall, Upper Saddle River, NJ.

Lee, H.L., 2000, "Creating value through supply chain integration", *Supply Chain Management Review*, Vol. 4, No. 4, pp. 30-36.

Lee, H.G., Clark, T., Tam, K.Y., 1999, "Can EDI benefit adopters?", *Information Systems Research*, Vol. 10, No. 2, pp. 186-195.

Lee, H.L., Padmanabhan, V., Whang, S., 1997, "Information distortion in a supply chain: the bullwhip effect", *Management Science*, Vol. 43, No. 4, pp. 546-558.

Li, H., 2000, "XML and industrial standards for electronic commerce", *Knowledge and Information Systems*, Vol. 2, No. 4, pp. 487-497.

Liebowitz, S.J., Margolis, S.E., 1990, “The fable of the keys”, *Journal of Law and Economics*, Vol. 33, No. 1, pp. 1-26.

Liebowitz, S.J., Margolis, S.E., 1994, “Network externality: an uncommon tragedy”, *Journal of Economic Perspectives*, Vol. 8, No. 2, pp. 133-150.

Liebowitz, S.J., Margolis, S.E., 1995, “Path dependence, lock-in and history”, *Journal of Law, Economics, and Organization*, Vol. 11, No. 1, pp. 205-226.

Lu, X.H., Huang, L.H., Heng, M.S.H., 2006, “Critical success factors of inter-organizational information systems - a case study of Cisco and Xiao Tong in China”, *Information & Management*, Vol. 43, No. 3, pp. 395-408.

Lu, E., Tsai, R., Chou, S., 2001, ”An empirical study of XML/EDI”, *Journal of Systems and Software*, Vol. 58, No. 3, pp. 271-279.

Luoma, J., Muhonen, T., Huomo, T., 1999, *Uudistuva tietotekniikka-arkkitehtuuri* (*Renewing Information Technology Architecture*), HM&V Research, Espoo, Finland.

Lyytinen, K., King, J.L., 2006, “Standard making: a critical research frontier for information systems research”, *MIS Quarterly*, Vol. 30, No. Special Issue, pp. 405-411.

Mackay, D., Rosier, M., 1996, “Measuring organizational benefits of EDI diffusion: a case of the Australian automotive industry”, *International Journal of Physical Distribution & Logistics Management*, Vol. 26, No. 10, pp. 60-78.

Malone, T.W., Yates, J., Benjamin, R.I., 1987, “Electronic markets and electronic hierarchies”, *Communications of the ACM*, Vol. 30, No. 6, pp. 484-497.

Manecke, N., Schoensleben, P., 2004, “Cost and benefit of Internet-based support of business processes”, *International Journal of Production Economics*, Vol. 87, No. 3, pp. 213-229.

March, S.T., Smith, G.F., 1995, “Design and natural science research on information technology”, *Decision Support Systems*, Vol. 15, No. 4, pp. 251-266.

Massetti, B., Zmud, R.W., 1996, “Measuring the extent of EDI usage in complex organizations: strategies and illustrative examples”, *MIS Quarterly*, Vol. 20, No. 3, pp. 331-345.

Medjahed, B., Benatallah, B., Bouguettaya, A., Ngu, A.H.H., Elmagramid, A.K., 2003, “Business-to-business interactions: issues and enabling technologies”, *VLDB Journal*, Vol. 12, No. 1, pp. 59-85.

Menard, S., 2002, *Applied Logistic Regression Analysis*, Sage Publications, Thousand Oaks, CA.

Microsoft, 2002, *BizTalk Server*, http://www.microsoft.com/biztalk/

Morell, J.A., 1994, "Standards and the market acceptance of information technology: an exploration of relationships", *Computer Standards & Interfaces*, Vol. 16, No. 4, pp. 321-329.

Mukhopadhyay, T., Kekre, S., 2002, "Strategic and operational benefits of electronic integration in B2B procurement processes", *Management Science*, Vol. 48, No. 10, pp. 1301-1313.

Mukhopadhyay, T., Kekre, S., Kalathur, S., 1995, "Business value of information technology: a study of electronic data interchange", *MIS Quarterly*, Vol. 19, No. 2, pp. 137-156.

Naylor, J.B., Naim, M.M., Berry, D., 1999, "Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain", *International Journal of Production Economics*, Vol. 62, No. 1-2, pp. 107-118.

Nelson, M.L., Shaw, M.J., Qualls, W., 2005, "Interorganizational system standards development in vertical industries", *Electronic Markets*, Vol. 15, No. 4, pp. 378-392.

Ngai, E.W.T., Wat, F.K.T., 2002, "A literature review and classification of electronic commerce research", *Information & Management*, Vol. 39, No. 5, pp. 415-429.

Nurmilaakso, J.M., Kettunen, J., Lehtonen, J.M., Saranen, J., Seilonen, I., 2001, "Seamless production planning and communication in distributed manufacturing: case ABB switchgear production", in Stanford-Smith, B., Chiozza, E. (Eds.), *E-work and E-commerce: Novel Solutions and Practices for a Global Networked Economy*, Vol. 2, e-2001, October 17-19, Venice, Italy, pp. 867-873.

OAG, 2004, *Integration Specification*, http://www.openapplications.org/oagis/

OASIS, 2004a, *Business Process Execution Language*, http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=wsbpel

OASIS, 2004b, *Electronic Business XML*, http://www.ebxml.org

OASIS, 2004c, *Universal Business Language*, http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=ubl

OASIS, 2005, *Organization for the Advancement of Structured Information Standards*, http://www.oasis-open.org

Olson, E., Williams, P., 2001, *E-commerce with Web-based Standards: A Case Study in Implementing RosettaNet Process Standards at Avnet*, http://www.rosettanet.org

papiNet, 2004, *papiNet*, http://www.papinet.org

Porter, M.E., 1985, *Competitive Advantage: Creating and Sustaining Superior Performance*, Free Press, New York, NY.

Power, D., 2005, “Supply chain management integration and implementation: a literature review”, *Supply Chain Management: An International Journal*, Vol. 10, No. 4, pp. 252-263.

Premkumar, G., Ramamurthy, K., Crum, M.R., 1997, “Determinants of EDI adoption in the transportation industry”, *European Journal of Information Systems*, Vol. 6, No. 2, pp. 107-121.

Premkumar, G., Ramamurthy, K., Nilakanta, S., 1994, “Implementation of electronic data interchange: an innovation diffusion perspective”, *Journal of Management Information Systems*, Vol. 11, No. 2, pp. 157-186.

Prosser, A., Nickl, A., 1997, “The impact of EDI on interorganizational integration”, *International Journal of Production Economics*, Vol. 52, No. 3, pp. 269-281.

Ramamurthy, K., Premkumar, G., 1995, “Determinants and outcomes of electronic data interchange diffusion”, *IEEE Transactions on Engineering Management*, Vol. 42, No. 4, pp. 332-351.

Ramamurthy, K., Premkumar, G., Crum, M.R., 1999, “Organizational and interorganizational determinants of EDI diffusion and organizational performance: a causal model”, *Journal of Organizational Computing and Electronic Commerce*, Vol. 9, No. 4, pp. 253-285.

Reimers, K., 2001, “Standardizing the new e-business platform: learning from EDI experience”, *Electronic Markets*, Vol. 11, No. 4, pp. 231-237.

Riggins, F.J., Mukhopadhyay, T., 1994, “Interdependent benefits from interorganizational systems: opportunities for business partner reengineering”, *Journal of Management Information Systems*, Vol. 11, No. 2, pp. 37-57.

RosettaNet, 2001, *Case Study: Arrow and UTEC Replace EDI-based Purchase Order Process with RosettaNet Standards*, http://www.rosettanet.org

RosettaNet, 2002a, *Achieving Streamlined Operations through Collaborative Forecasting and Inventory Management: STMicroelectronics E-chain Optimization Project*, http://www.rosettanet.org

RosettaNet, 2002b, *Co-adoption of RosettaNet Standards: A Return on Investment Framework*, http://www.rosettanet.org

RosettaNet, 2003, *Intel and Shinko Use RosettaNet Standards to Build Forecast-to-cash Procurement Process*, http://www.rosettanet.org

RosettaNet, 2004, *RosettaNet*, http://www.rosettanet.org

RosettaNet Japan, 2003, *ROI of RosettaNet Standards Implementation: Case Study Report*, http://www.rosettanet.gr.jp

Russell, S., Norvig, P., 1995, *Artificial Intelligence: A Modern Approach*, Prentice-Hall, Englewood Cliffs, NJ.

Scala, S., McGrath, R., 1993, "Advantages and disadvantages of electronic data interchange: an industry perspective", *Information & Management*, Vol. 25, No. 2, pp. 85-91.

Scannell, E., 2005, "Gartner: IBM maintains integration lead", *InfoWorld*, April 12.

SCC, 2005, *Supply-chain Operations Reference-model*, http://www.supply-chain.org

Seilonen, I., Nurmilaakso, J.M., Jakobsson, S., Kettunen, J., Kuhakoski, K., 2001, "Experiences from the development of an XML/XSLT-based integration server for a virtual enterprise type co-operation", in Thoben, K.D., Weber, F., Pawar, K.S. (Eds.), *Proceedings of the 7th International Conference on Concurrent Enterprising: Engineering the Knowledge Economy through Co-operation*, ICE 2001, June 27-29, Bremen, Germany, pp. 321-328.

Shapiro, C., Varian, H., 1999, *Information Rules: A Strategic Guide to the Network Economy*, Harvard Business School Press, Boston, MA.

Shim, S.S.Y., Pendyala, V.S., Sundaram, M., Gao, J.Z., 2000, "Business-to-business e-commerce frameworks", *IEEE Computer*, Vol. 33, No. 10, pp. 40-47.

Simchi-Levi, D., Kaminsky, P., Simchi-Levi, E., 2000, *Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies*, McGraw-Hill, Boston, MA.

Soliman, K.S., Janz, B.D., 2004, "An exploratory study to identify the critical factors affecting the decision to establish Internet-based interorganizational information systems", *Information & Management*, Vol. 41, No. 6, pp. 697-706.

Srinivasan, K., Kekre, S., Mukhopadhyay, T., 1994, "Impact of electronic data interchange technology on JIT shipments", *Management Science*, Vol. 40, No. 10, pp. 1291-1304.

Sriram, R.S., Arunachalam, V., Ivancevich, D.M., 2000, "EDI adoption and implementation: an examination of perceived operational and strategic benefits and controls", *Journal of Information Systems*, Vol. 14, No. 1, pp. 37-52.

Staab, S., Van der Aalst, W., Benjamins, V., Sheth, A., Miller, J., Bussler, C., Maedche, A., Fensel, D., Gannon, D., 2003, "Web Services: been there, done that?", *IEEE Intelligent Systems*, Vol. 18, No. 1, pp. 72-85.

Stefansson, G., 2002, "Business-to-business data sharing: a source for integration of supply chains", *International Journal of Production Economics*, Vol. 75, No. 1-2, pp. 135-146.

Sundaram, M., Shim, S., 2001, “Infrastructure for B2B exchanges with RosettaNet”, in *The 3rd International Workshop on Advanced Issues of E-commerce and Web-based Information Systems*, WECWIS 2001, June 21-22, Milpitas, CA, pp. 110-119.

Tan, K., 2001, “A framework of supply chain management literature”, *European Journal of Purchasing & Supply Management*, Vol. 7, No. 1, pp. 39-48.

Tan, G.W., Shaw, M.J., Fulkerson, B., 2000, “Web-based supply chain management”, *Information Systems Frontiers*, Vol. 2, No. 1, pp. 41-55.

Threlkel, M.S., Kavan, B., 1999, “From traditional EDI to Internet-based EDI: managerial considerations”, *Journal of Information Technology*, Vol. 14, No. 4, pp. 347-360.

Tikkala, J., Kotinurmi, P., Soininen, T., 2005, “Implementing RosettaNet business-to-business integration platform using J2EE and Web Services”, in *Proceedings of the 7th International IEEE Conference on E-commerce Technology*, CEC 2005, July 19-22, Munich, Germany, pp. 553-558.

Trent, R.J., Monczka, R.M., 1998, “Purchasing and supply management: trends and changes throughout the 1990s”, *International Journal of Purchasing and Materials Management*, Vol. 34, No. 4, pp. 2-11.

UNECE, 2005, *Electronic Data Interchange for Administration, Commerce and Transport*, http://www.unece.org/trade/untdid/

Venkatraman, N., Zaheer, A., 1990, “Electronic integration and strategic advantage: a quasi-experimental study in the insurance industry”, *Information Systems Research*, Vol. 1, No. 4, pp. 377-393.

Von Westarp, F., Weitzel, T., Buxmann, P., König, W., 1999, “The status quo and the future of EDI: results of an empirical study”, in Pries-Heje, J., Ciborra, C., Kautz, K., Christiaanse, E., Avison, D., Heje, C. (Eds.), *Proceedings of the 7th European Conference on Information Systems*, ECIS 1999, June 23-25, Copenhagen, Denmark, pp. 719-731.

W3C, 2004, *Extensible Markup Language*, http://www.w3.org/TR/REC-xml/

W3C, 2005, *World Wide Web Consortium*, http://www.w3.org

Wacker, J.G., 2004, “A theory of formal conceptual definitions: developing theory-building measurement instruments”, *Journal of Operations Management*, Vol. 22, No. 6, pp. 629-650.

Wareham, J., Zheng, J.G., Straub, D., 2005, “Critical themes in electronic commerce research: a meta-analysis”, *Journal of Information Technology*, Vol. 20, No. 1, pp. 1-19.

WfMC, 2004, *XML Process Definition Language*, http://www.wfmc.org/standards/docs.htm

Willcocks, L.P., Lester, S., 1999a, “Information technology: transformer or sink hole?”, in Willcocks, L.P., Lester, S. (Eds.), *Beyond the IT Productivity Paradox*, Wiley, Chichester, United Kingdom, pp. 1-36.

Willcocks, L.P., Lester, S., 1999b, “In search of information technology productivity: assessment issues”, in Willcocks, L.P., Lester, S. (Eds.), *Beyond the IT Productivity Paradox*, Wiley, Chichester, United Kingdom, pp. 69-97.

Wilson, T., 2000, “EDI is alive and kicking, study says”, *InternetWeek*, February 21.

Yen, B., Farhoomand, A., Ng, P., 2004, “Constructing an e-supply chain at Eastman Chemical Company”, *Journal of Information Technology*, Vol. 19, No. 2, pp. 93-107.

Yin, R.K., 1994, *Case Study Research: Design and Methods*, Sage Publications, Thousand Oaks, CA.

Zhao, Y., Sandahl, K., 2000, “XML-based frameworks for Internet commerce”, in *Proceedings of the 2nd International Conference on Enterprise Information Systems*, ICEIS 2000, July 5-7, Stafford, United Kingdom, pp. 511-516.

Zhu, K., Kraemer, K.L., Gurbaxani, V., Xu, S., 2006, “Migration to open-standard interorganizational systems: network effects, switching costs, and path dependency”, *MIS Quarterly*, Vol. 30, No. Special Issue, pp. 515-539.

Zhu, K., Kraemer, K., Xu, S., 2003, “Electronic business adoption by European firms: a cross-country assessment of the facilitators and inhibitors”, *European Journal of Information Systems*, Vol. 12, No. 4, pp. 251-268.

Zuboff, S., 1988, *In the Age of the Smart Machine: The Future of Work and Power*, Basic Books, New York, NY.

ISBN 978-951-22-9073-4
ISBN 978-951-22-9074-1 (PDF)
ISSN 1795-2239
ISSN 1795-4584 (PDF)