Abstract
With deeper levels of external process integration and a growing number of electronic business relationships, enterprises are striving to become more interoperable with their business partners. While two-way integration linkages have mostly been realized as point-to-point connections with a handful of business partners, new integration technologies such as Web services and XML give enterprises the opportunity to pursue more cost-efficient and scalable ways of external business process integration. This research develops a model for service-based B2B interoperability that leverages Web service technologies for implementing industry standards. The authors instantiate the conceptual model in a B2B scenario in the automotive industry, where a consortium of automotive manufacturers and suppliers are currently redesigning their interorganizational engineering change management processes. From the evaluation, the authors suggest that the specification of standards related to pragmatics, semantics and syntax has to be complemented by additional design rules which define how industry standards are mapped to a public Web service design. The paper concludes with a revised model for service-based interoperability and discusses implications for B2B standardization.

Keywords: B2B integration, interoperability, standard development, Web services, service-oriented architecture (SOA), XML document engineering

INTRODUCTION
Organization boundaries are becoming more fluid. For enterprises wishing to establish a growing number of electronic relationships, interoperability is crucial. Being ‘interoperable’ refers to the ability to integrate business processes with business partners, understand and process exchanged data, seamlessly integrate data into internal ICT systems and enable its beneficial use (Legner and Lebreton 2007, Yang and Papazoglou 2000). In an empirical survey, 40% of large European companies across all industries consider interoperability as critical for them to do business (European Commission 2005). For the sole area of concurrent product design and engineering, Brunnermeier and Martin (2002) estimate that ‘imperfect interoperability costs the US automotive industry about $1 billion per year and delays the introduction of new vehicles by at least two months’.

In order to establish interoperability between enterprises, a huge number of standard development organizations – among them industry associations such as RosettaNet, GS1 or CIDX and multinational standardization bodies such as UN/CEFACT and ISO – are developing and promoting standards for collecting, presenting and transferring information between organizations. Although B2B standards have been the subject of many recent publications (Angeles et al. 2001, Löwer 2005, Markus et al. 2006, Reimers and Li 2005, Zhu et al. 2006), most of the research explores the adoption and diffusion of standards. Little attention has been paid thus far to the design of the suggested standards and their quality. This contrasts with the observation that adherence to a specific B2B standard does not necessarily create interoperability. On the one hand, many standards lack specifications on the semantic and pragmatic layers and thereby require additional ex ante agreements before electronic business processes across company boundaries can take place (McAfee 2005b, Reimers 2001). On the other hand, the complexity of existing standards increases adoption costs and entails the risk of ambiguous interpretation when it comes to their implementation. In the past few years, Web services and service-oriented architectures (SOA) have emerged as an enhanced concept for systems integration in heterogeneous environments (Erl 2005,
Papazoglou and Georgakopoulous 2003, W3C 2004). Many authors (e.g., Bussler 2003, Feuerlicht 2005) postulate that in the future an enterprise could simply expose application functionality as a Web service and thereby realize machine-to-machine process integration with its business partners.

Given the inherent difficulties in external integration, the interesting questions of how Web services should be used in the B2B context and whether they are able to improve interoperability among organizations remain to be answered. More specifically, our research investigates the following questions:

- How can Web service interoperability be leveraged for realizing standard-based B2B integration?
- Does the implementation of a vertical industry standard using Web services reduce the need for bilateral agreements in B2B relationships?
- What conclusions can be drawn for future B2B standardization?

Since our primary goal is to give prescriptions on how to use Web services for achieving interoperability in B2B relationships, this research can be classified as ‘Theory for Design and Action (Type V)’ according to the taxonomy suggested by Gregor (2006). In devising and evaluating the proposed model, we follow the principles of design science as suggested by Hevner et al. (2004).

The remainder of this paper is structured as follows: The next section summarizes prior research related to B2B integration, standardization and service-oriented architecture. Then, we define and explain the research approach and describe the research process. Building on the semiotic structure of communication, we develop a model for service-based interoperability which is then applied to a B2B scenario in the automotive industry. The paper concludes with a summary of the findings from the field study and a discussion of the implications for future B2B standardization.

**PRIOR RESEARCH**

This research relates to three distinct streams of prior work: (1) From their intensive studies of the role and effects of interorganizational systems (IOS), IS researchers have elaborated on the different forms of electronic B2B integration and their characteristics; (2) Given the crucial role of standards in facilitating many-to-many interactions, an increasing body of research investigates standard development and its diffusion; and (3) More recently, the attention of researchers has turned to SOA and Web services. As these innovations build on open Web technologies, they are expected to completely overhaul interorganizational integration.

**B2B integration**

Despite the rapid diffusion of the Internet, the most frequent form of two-way machine-to-machine integration supporting B2B relationships to date has been Electronic Data Interchange (EDI), which is still ahead of XML-based data exchange in many industries (Beck and Weitzel 2005, European Commission 2005). From its adoption, researchers have gained the insight that the use of technology in interorganizational relationships is most beneficial if accompanied by process innovation (Clark and Stoddard 1996; Riggins and Mukhopadhyay 1994). However, many challenges arise if information systems are required to handle more complex process interactions (Brousseau 1994). Referring to the semiotic structure of communication, Kubicek (1992), Reimers (2001) and McAfee (2005b) argue that electronic system linkages (machine-to-machine) require additional levels of interorganizational agreements as compared to human-to-human interaction. As depicted in Table 1, at the lowest level, information systems have to share agreements on how data is to be transported over a network, e.g. through standard Internet protocols such as http. Since information systems are not as flexible as humans in interpreting documents, further ex ante agreements need to be made explicit and formalized in order to allow machine-to-machine interaction. The latter include document syntax defining the type and structure of messages, semantic annotations describing the meaning and purpose of messages in the business context, and process level information detailing the interaction patterns as pragmatics.

There is empirical evidence that the difficulties of specifying machine-to-machine interactions have limited the migration of companies to two-way integration of their business processes with external partners. Whereas customer and supplier portals are widely used, machine-to-machine integration is mostly restricted to high-volume supply chain interactions (mainly order and shipping information) with a handful of large partners. This is due to the high investments required for setting up the infrastructure and the significant effort for ‘on-boarding’ business partners (Markus and Bashein 2006, McAfee 2005b), which also hamper adoption by smaller companies (Beck and Weitzel 2005, Iacovou et al. 1995).

**B2B standardization**

In their early study, Benjamin et al. (1990) reported that insufficient availability of standards has been the most important barrier to interorganizational integration. In the meantime, a large number of standards have emerged, but many still fail to achieve broader dissemination (European Commission 2005, Quantz and Wichmann 2003). This has led to a continuing debate
about the way standards are created and adopted. Standardization has been analysed through multiple theoretical lenses, among them institutional theory (Damsgaard and Lyytinen 2001), actor-network theory (Hanseth et al. 2006, Löwer 2005), transaction cost theory (Reimers and Li 2005) and collective action dilemmas (Markus et al. 2006). While standards are expected to reduce transaction costs, network effects are key to explaining the adoption of standards. Excess inertia, start-up problems and lock-in effects are typical of e-business scenarios in which too many standards and diverse technical solutions discourage potential members from taking the disproportionate risk of deciding on a specific implementation (Buxmann et al. 2005, Gowrisankaran and Stavins 2004, Katz and Shapiro 1985, Stabell and Fjeldstad 1998). There is increasing awareness that adoption costs, which are determined by the organizational and technical complexity of making process changes, are a significant barrier to the diffusion of open standards (Zhu et al. 2006).

A relatively small research community has studied the scope and limitations of the many domain-specific standards that have been launched over the past decades and which we denote as vertical industry standards. Scholars have observed that to date standardization has only been successful with regard to communication services and on the syntactical level (Bussler 2003, McAfee 2005b). Historically, EDI-based standards (e.g., UN/EDIFACT or ANSI X.12) were the first to specify electronic business documents based on a rigid message syntax and relying on a proprietary communication infrastructure, the so-called value added network (VAN). They have often been criticized for their fragmentation and the multitude of EDI specifications in use (Angeles et al. 2001). Prior to communicating electronically by sending and receiving EDI messages, enterprises have to bilaterally clarify the underlying coordination processes and interorganizational arrangements, thus resulting in point-to-point connections (Brousseau 1994, Damsgaard and Truex 2000). This failure to address semantic and pragmatic issues is denoted as ‘organization gap’ by Kubicek (1992) and leads Brousseau (1994) to call for a ‘standardization of coordination processes’.

In the context of Internet-based business process integration, open Web protocols are widely accepted for transport and communication and eXtensible Markup Language (XML), which is a ‘tagging’ language, has become very popular for defining the message syntax. Since the emergence of XML, industrial associations increasingly specify XML-based business documents (Nurmilaakso et al. 2006), e.g. ChemXML as part of CIDX standards in the chemical industry. In addition, standardization bodies have started to address semantic harmonization across company boundaries, e.g. with the ISO specifications for Currency and Country Codes or the UN/CEFACT Core Component Library. However, standardization has not yet fully resolved the issues on the pragmatic level. RosettaNet Partner Interface Protocols (PIPs) pursue this direction by defining interaction patterns in the high-tech industry (RosettaNet 2001).

### Web services and service-oriented architecture (SOA)

Interorganizational systems technology has been completely overhauled since the mid 1990s by the
emergence of the Internet which provides a more flexible and much cheaper platform for electronic external process integration than previous EDI-based value added networks (Bussler 2003, Christiaanse 2005, Papazoglou and Georgakopoulos 2003). More recently, service-oriented architectures and Web services have emerged as an enhanced concept for integration in heterogeneous environments (Erl 2005, Papazoglou and Georgakopoulos 2003, W3C 2004) and are expected to stimulate interorganizational process integration (Daniel and White 2005, Hagel and Brown 2001). The World Wide Web Consortium defines a Web service as ‘a software application identified by a URI, whose interfaces and bindings are capable of being defined, described and discovered as XML artefacts. A Web service supports direct interaction with other software agents using XML-based messages exchanged via Internet protocols’ (W3C 2004). Web services build on a number of open standards, in particular XML to tag data, SOAP to transfer data and WSDL for service interface descriptions (Alonso et al. 2003, Umapathy and Purao 2007). Services foster interoperability through stable interfaces that are independent from implementation details and comprise a technical and functional service description. Although SOA is supposed to increase external integration capabilities, the particular contribution of service-orientation for B2B integration is not well understood. So far, only few examples exist for the application of service-oriented concepts in the B2B context, e.g. in e-tourism by Fodor and Werthner (2004), in the travel industry by Feuerlicht (2005) or in the telecommunications sector by Zimmermann et al. (2005). However, the question remains how Web services interoperability can be leveraged for realizing standard-based B2B integration.

RESEARCH METHOD

In view of our research questions, we targeted our efforts at designing more interoperable B2B interactions that could reduce the need for bilateral negotiations on the specified levels of agreement and leverage Web services interoperability. We adopted design science as a research framework, which is recommended for the scientific study in the field of IT where artificial, human-made phenomena, such as organizations and/or information systems are examined (March and Smith 1995). The result of our research is a cross-layer architecture model for interorganizational process and system integration. This model comprises a set of constructs as well as their relationships and can be considered a viable artefact in the sense of design theory (Gregor 2006, Hevner et al. 2004). Table 2 depicts our research process which spanned a 3-year period. The three phases in the research process reflect the main activities in design science according to March and Smith (1995) and Hevner et al. (2004), namely the construction, evaluation and refinement of the artefact. They can be related to the process steps in design science as outlined by (Takeda et al. 1990).

In the first phase of our research, from October 2004 to September 2005, we developed the model for service-based interoperability. For this purpose, we applied conceptual modelling, which is generally defined as a process of developing a (semi-)formal representation of selected phenomena of a certain real-world domain (Shanks et al. 2003) that serves for detecting user requirements (Wand and Weber 2002). During this phase, we designed and formalized the constructs on the four semiotic levels of agreement. In addition, we designed the means by which the business-level models specifying the pragmatics and semantics can be trans-
lated into constructs relevant for implementation based on Web services and a service-oriented architecture. Constructs and relationships were documented as a meta-model.

The second phase in our research process was targeted at the experimental evaluation of the architectural model based on a field study. Over a period of 15 months, from October 2005 to February 2007, the authors worked with six automotive companies to instantiate the architecture model for the specific scenario of engineering change management and to realize a pilot implementation. We chose this particular scenario for the following reasons: (1) The automotive industry has broad experience in B2B integration due to its long history in EDI-based supplier relationships. In this regard, automotive manufacturers and suppliers are aware of various B2B interoperability issues. They can also be considered ‘IT-savvy’, which made it possible to run a pilot implementation; (2) Engineering change management has been subject to a recent industry standardization initiative by the Association of German Automotive Manufacturers (VDA). This initiative resulted in VDA Recommendation 4965, which represents a well-documented and comprehensive industry standard; and (3) In view of the wide range of implementation variants of VDA Recommendation 4965, which range from manufacturer-neutral clients to EDI, automotive companies are pressing for solutions which have greater interoperability through SOA and Web services.

As part of the field study, the project partners implemented the Web service design developed as the instantiation of the architectural model on the basis of their integration platforms (IBM WebSphere, SAP NetWeaver and Inubit). Since none of the companies had been using Web services for B2B integration prior to our study, this pilot implementation was also supported by technology vendors. An additional reference implementation was realized by the authors based on the BEA WebLogic platform. The main criterion for the evaluation was the interoperability of the implementations realized by the different partners. For this purpose, we analysed the interorganizational process interaction based on invocations of the public Web service.

Thus, our research closely follows the guidelines outlined by Hevner et al. (2004). Our research results are viable artefacts in the form of an architectural model for service-based B2B interoperability (‘design as an artefact’). We applied rigorous methods in the construction of the model, which we deduced from prior research on B2B integration, standardization and Web service concepts, as well as in its evaluation (‘research rigour’). Utility, quality and efficacy of our model are demonstrated by an experimental design evaluation method (‘design evaluation’). By conducting a field study, we were able to instantiate the conceptual model in a real-world scenario and evaluate it on the basis of a pilot implementation. The instantiation revealed some deficiencies in our conceptual model, which we addressed by developing additional design rules for the relationships between constructs. Thus, our design process was iterative and implied a generate/test cycle (‘design as a search process’).

MODEL FOR SERVICE-BASED INTEROPERABILITY

Our model starts from the assumption that interoperability can be increased if constructs are defined for all required levels of interorganizational agreement and if these constructs reflect widely accepted standards. The following section outlines the architectural layers as well as the constructs of our model and their relationships.

Architectural layers

Since enterprise systems increasingly incorporate SOA concepts and thereby facilitate integration into internal backend systems based on Web services, we consider Web service standards and the underlying Internet protocols to form the foundation for electronic B2B process integration. However, according to the semiotic structure of communication they only cover the lower two layers namely (1) transport and communication and (2) syntax (Kubicek 1992, McAfee 2005b, Reimers 2001). The upper two layers, namely (3) semantics and (4) pragmatics, are domain-specific and have to be addressed by vertical industry standardization. For these two layers, our model relies on constructs that have been suggested by prior research related to interorganizational business process design (Legner and Wende 2007, Theling et al. 2005, van der Aalst and Weske 2001). They comprise a process model describing the interorganizational or public process, an organizational model defining roles and responsibilities, an information model specifying the relevant information entities and an interface model that refines the organizational interface and details the information flow.

Table 3 summarizes the conceptual model for service-based interoperability which comprises a defined set of ‘public’ constructs that business partners have to agree on in interorganizational relationships. It also depicts the contribution of Web service concepts, including the open Internet protocols they are based on, as well as industry standardization. Once the public constructs are defined and implemented, they establish stable interfaces for electronic interaction with external partners.

Pragmatic and semantic level of agreement

Vertical industry standards are supposed to define the semantics and pragmatics of the B2B relationship. With
regard to the pragmatics, our model defines the following constructs:

- The organizational or role model describes the different roles that are visible to external partners in the cooperation. It defines their specific responsibilities and functions on the organizational and position levels; and
- The public process model is the central element of the framework for modelling interorganizational processes. It describes the activity flow and the interaction between external actors in their specific roles. Thus, our model builds on prior work related to distributed business processes (Liu and Shen 2003) as well as B2B standardization (OMG 2006, RosettaNet 2001), which introduced the distinction between the public (or external) and the private (or internal) view. The public process represents a view of the entire interorganizational processes that conceals details in the private processes of the individual partners by using abstraction concepts.

This set of constructs is complemented by two artefacts specifying the semantics:

- The information model creates a common business vocabulary for the different parties involved in the B2B collaboration. It describes the main business objects by defining attributes and their range of values as well as associations between business objects; and
- The interface model details the process interfaces between the organization units involved. It comprises the information flow, i.e. the business documents or messages which are exchanged, and the control flow, i.e. parameters describing the expected service level or response time. Messages typically aggregate a set of business objects as defined in the information model.

Syntax, communication and transport level of agreement

Web service standards build on open Internet protocols (http and TCP/IP) to ensure the transport, and XML as syntax for exchanging business information. Web services add to these Internet standards by defining how service providers and users interact:

- on the syntax layer, WSDL defines the description of service interfaces. The abstract part of a WSDL service specification defines data types, messages, service operations and port types, whereas the concrete part describes protocol binding, the address (using the Uniform Resource Identifier, URI) and other information. Service operations require XML messages (business documents) as input and output parameters; and
- on the communication layer, SOAP specifies communication protocols for exchanging XML messages between a service provider and a service consumer.

Relationships between constructs

Whereas the single constructs discussed above are not necessarily new, the different layers are mostly treated separately in the literature. In reality, interoperability is only achieved if all semiotic layers are addressed simultaneously. Thus, the main contribution of our model is the formalized set of constructs and their relationships. If an industry standard has been defined by the constructs mentioned earlier, it can be systematically translated into a public Web service interface by applying the following design and mapping rules (cf. Figure 1). Every interaction between business partners defined in the public process has to be supported by a dedicated service operation (relation 1). This service operation can be invoked by business partners and is specified by the WSDL. Since we recommend realizing B2B interactions as platform-independent, document-oriented Web services, the input and output parameters of the service operation are business documents (or messages). These business documents are XML-representations of the messages specified by the interface model of the vertical industry standard (relation 2). Business documents are composed of different information entities that represent the business information objects and are translated into corresponding data types (relation 3). Once the public
Web service interface has been specified and implemented by different organizations, they are able to coordinate their cross-organizational workflows and synchronize their information statuses by simple service invocation.

APPLICATION TO THE AUTOMOTIVE INDUSTRY

This section applies and instantiates the model for service-based interoperability in the scenario of collaborative engineering change management (ECM) between automotive manufacturers and their suppliers.

Vertical industry standard

Engineering change management is typically performed interactively between automotive manufacturers and suppliers. Its purpose is the evaluation of change requests and the subsequent real-time propagation of engineering changes in development, planning and manufacturing processes. Possible triggers for changes include modification in product design, quality and safety problems. Developed in a joint effort by suppliers, manufacturers and software vendors and issued by the Association of German Automobile Manufacturers (VDA), VDA Recommendation 4965 creates a common understanding of engineering change management, in particular the processing of engineering change requests (ECR). As a pure business standard, it describes role, process and data models without defining the physical implementation of the standard.

The organizational model comprises two roles at the organizational level as well as nine roles at the functional level. The organization that assumes the coordinator role has overall responsibility for processing the engineering change request, whereas the participant role assists in commenting on and evaluating the change. Roles at the functional level include the engineering change manager, one or more comment performers (including external parties) and the approver.

The reference process as defined by VDA Recommendation 4965 incorporates an informal process description (including phases, milestones and synchronization points) as well as UML activity diagrams. It describes in detail how an engineering change request should be processed once a need for change has been detected and possible solution alternatives have been described. Engineering change requests must then be analysed for effectiveness and feasibility. This is followed by a comprehensive economic and technical evaluation, which provides the basis for a decision on the change request and its rollout to production.

With regard to the semantics, the VDA recommendation contains a data dictionary and a data model as the basis for message definition. The data model, which is
formulated in Express-G, can be considered a comprehensive information model of an engineering change request. It comprises the basic description of an ECR (in the ECR_header class), classification and status information (e.g., ECR_classification, ECR_status, ECR_acceptance) as well as the documentation of further analyses performed during ECR processing. So far, process interface descriptions are restricted to message definitions and do not include any further non-functional specifications, e.g., service-level agreements. These interfaces are defined by linking each message type to the optional or mandatory classes which can or should be contained in the message.

Table 4 depicts the coverage of VDA Recommendation 4965 related to the different levels of agreement as defined earlier. Since it addresses all relevant constructs for describing pragmatics and semantics, it can be considered a comprehensive industry standard. However, public processes and the interface model are not completely specified. Consequently, these gaps had to be filled prior to deriving the service design. In the course of the field study, we developed a more detailed model of the public process and additional specifications for interpreting the information model.

### Public ECR business service

As a vertical industry standard, the translation into a Web service design was deliberately outside the scope of the VDA standardization initiative (c.f. Table 4). In the course of the field study, we applied the design and mapping roles outlined in the architecture model in order to develop the Web service design – known as the ECR Business Service. The design was validated in an iterative process involving business and IT integration experts from the different companies in order to ensure as much interoperability as possible. The following section describes the most relevant aspects of the service design: (1) the messages that the service operations expect as input or output parameter and the fundamental data objects they are composed of; and (2) the service operations that characterize the service interface.

**Business documents (XML schema definition).** Based on the information model and the messages defined by the VDA Recommendation, business documents – as service input and output – have been specified as XML schema representation. Although the information model exists, relatively high degrees of freedom exist when deriving the schema representation. They relate to (1) the mapping of certain constructs, e.g., inheritance or abstraction, which the original data model represents in Express-G notation, into UML and later XML schema representation; and (2) the general structure of the XML schema.

In the case of the ECR Business Service, we decided to develop the message structure following the technology-neutral framework of OAGi for designing Business Object Documents (BODs) as depicted in Figure 2.

### Table 4. Coverage of VDA recommendation 4965

<table>
<thead>
<tr>
<th>Levels of agreement</th>
<th>Constructs</th>
<th>VDA Recommendation 4965, Version 1.0</th>
<th>Specification (1)/(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pragmatics</td>
<td>Role model covering</td>
<td>Role model covering</td>
<td>U/U</td>
</tr>
<tr>
<td></td>
<td>Organizational and role model</td>
<td>Organizational and role model</td>
<td>U/U</td>
</tr>
<tr>
<td></td>
<td>Public process</td>
<td>Public process</td>
<td>K/U</td>
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<tr>
<td></td>
<td>Process description consisting of</td>
<td>Process description consisting of</td>
<td>K/U</td>
</tr>
<tr>
<td>Semantics</td>
<td>Information model</td>
<td>Information model</td>
<td>U/U</td>
</tr>
<tr>
<td></td>
<td>Data model (in Express-G notation)</td>
<td>Data model (in Express-G notation)</td>
<td>U/U</td>
</tr>
<tr>
<td></td>
<td>Interface model/messages</td>
<td>Interface model/messages</td>
<td>K/U</td>
</tr>
<tr>
<td>Syntax</td>
<td>Service interface definition</td>
<td>Service interface definition</td>
<td>Not covered</td>
</tr>
<tr>
<td></td>
<td>Input/output parameters</td>
<td>Input/output parameters</td>
<td>Not covered</td>
</tr>
<tr>
<td>Communication and transport</td>
<td>Communication protocol</td>
<td>Communication protocol</td>
<td>Not covered</td>
</tr>
<tr>
<td></td>
<td>Transport protocol</td>
<td>Transport protocol</td>
<td>Not covered</td>
</tr>
</tbody>
</table>

Notes: U fully specified; K partly specified; _ not specified; (1) Specification by vertical industry standard (VDA 4965); (2) Specification after refinement by project group.
The ECR messages are split into ApplicationArea and DataArea. The ApplicationArea provides the meta-information describing the message and processing instructions. Thus far, the ApplicationArea is used for sender-specific information and error handling. The actual payload of the message is defined in the DataArea, which contains four components for an engineering change message. The MessageRequestContext holds business control information, e.g. DUNS number, which is stipulated as message context by the VDA Recommendation. Whereas the MessageSpecificPart contains the specific data components for the appropriate message, the MessageBasicPart encapsulates the data components common to all messages. The element MessageUserDefinedPart is another message element used to extend messages in accordance with bilateral agreements and at the same time to ensure separation from the VDA-specific parts of the message.

**Service operations.** A major design decision has to be taken on whether to apply strongly typed versus generic operations (Zimmermann et al. 2003). While generic solutions may cope with upcoming changes in the interface and information model better than strongly typed interfaces, the loss of semantics outweighs the advantage when it comes to maintainability of the interface and service orchestration in a fully-fledged SOA. The single operations of the ECR Business Service directly reflect the interorganizational interactions defined by the reference process in the VDA Recommendation. As outlined in Figure 3, the names of the operations refer to the activity they are invoking and the business information object they require as input. Each of these 11 operations requires a different set of information as input parameter and expects the XML representation of the respective message. Since the business reply to the input message typically requires human intervention and constitutes a long-running transaction, the ECR Business Service merely returns a synchronous acknowledge message which signals correct receipt at the partner’s end. The business reply is sent asynchronously by means of an additional service invocation.

**FINDINGS**

The field study and in particular the pilot implementation can be considered a ‘proof of concept’ for the
Industry standards interoperability (semantic and pragmatic levels)

From the instantiation and the piloting, all industry partners agreed that, if fully specified, the constructs outlined at the semantic and pragmatic levels enhance understanding of the complex interorganizational inter-relationships of the individual ECM processes. This general consent was favoured by the fact that all companies were able to map their individual process, information and organizational models to the defined public constructs. Interestingly, we experienced some issues related to the process description by the industry standard, which does not fully cover the relevant constructs as outlined in the suggested model (c.f. Table 4). Although dealing with a relatively mature industry standard (e.g., compared to the recent VDA recommendation on Quality Data Exchange, which focuses exclusively on messages), VDA Recommendation 4965 does not adequately specify the interorganizational coordination, in particular the public process and process interface model. Additional issues result from the complexity of the standard, which encompasses a large number of process variants and abundant optional attributes (only 10% of the attributes are classified as mandatory). In the case of inadequate or ambiguous standardization, the constructs outlined in the conceptual model have been refined in the course of the field study, mainly by adding process specifications and defining implementation guidelines for the messages.

Web service interoperability (syntax, communication and transport levels)

With regard to technical interoperability, the evaluation of the pilot implementation confirms that Web service standards foster interoperability and reduce implementation efforts for external integration. The participants in the field study were able to implement the ECR Business Service on different platforms (e.g., SAP NetWeaver, IBM WebSphere, BEA WebLogic) and expose it to their business partners within a timeframe of 10 to 15 days. The pilot implementation showed that the core WS standards, which include SOAP, WSDL and XML schema, are without exception supported by middleware and/or SOA platforms. The technical interoperability could be successfully tested by invoking services from other partners. The WS-I basic profile specification (WS-I 2005), which was defined by WS-I to fill the gaps in WS standards, is supported by most vendors and made a significant contribution in this context.

Vertical transformation of the different levels of agreement

Although the pilot demonstrates that the conceptual model comprises all the relevant constructs to specify interoperable B2B relationships, there are multiple ways of translating the pragmatic and semantic specifications into a ‘public’ Web service design. In this regard, the initial set of mapping and design principles (cf. Figure 1) was not sufficient. Designing the ECR Business Service led to various suggestions for enhancements, namely the use of OAGi naming and design rules for creating XML-representations of the specified messages. The relevance of design rules for the vertical transformation is underpinned by the fact that a competing service design that builds on an existing OMG standard was recently suggested for implementing VDA Recommendation 4965. Whereas the ECR Business Service derives 11 service operations from the interactions outlined in the reference process, OMG PLM Services leverage an existing generic service operation write_messages that was originally created for exchanging product data. Consequently, OMG PLM Service 2.0 exposes a totally different service interface than the ECR Business Service. Although derived from the same industry standard, little or no interoperability exists between companies if they implement these different service designs.

Conclusion and enhanced model for service-based interoperability

The instantiated model and its pilot implementation for engineering change management can be considered a ‘proof of concept’ for service-based interoperability. They demonstrate that the constructs outlined in the conceptual model are sufficient for specifying interoperable, service-based B2B relationships, and their implementation is feasible when based on state-of-the-art SOA platforms. It also demonstrates that industry standards can be systematically translated into Web service concepts if, as a prerequisite, they fully specify the relevant constructs representing the pragmatics – i.e. an organizational and a public process model – as well as the semantics – i.e. an information and interface model. However, the field study also reveals that the pure definition of standards on every level of agreement is not sufficient to ensure interoperability. In fact, if no mapping and design rules for the vertical transformation of the constructs are specified, the same industry
standard can easily lead to competing service design proposals with limited or no interoperability. With regard to the conceptual model for service-based interoperability, this underlines the importance of mapping rules and design principles that specify vertical transformation of pragmatic and semantic level constructs onto the Web service interface. We have consequently enhanced our model for service-based interoperability by a set of design rules that address the following issues:

- Translating the information model and the interface model into a modular message design and resulting XML schema definition (Relation 2 in Figure 1). Naming and design rules as issued by the United Nations Center for Trade Facilitation and Electronic Business (UN/CEFACT 2006b) and OAGIS (OAGi 2006) guide the message assembly.
- Using standardized business vocabulary (Relation 3 in Figure 1). The use of semantic building blocks like the UN/CEFACT Core Components Library (CCL) and the Core Component Technical Specification (CCTS) provide the underlying business vocabulary.
- Deriving service operations (Relation 1 in Figure 1). Our design recommendation is to use strongly typed interfaces, which increase maintainability of the interface and service orchestration in a fully-fledged SOA.

DISCUSSION

From the existing work on B2B integration, we have argued that the use of standards on all semiotic levels of agreement will increase interoperability in electronic B2B relationships. The main contribution of this paper is a model for service-based interoperability that specifies constructs at the required semiotic levels of communication. Whereas industry standards are supposed to cover pragmatics and semantics, they should rely on Web services and underlying Internet standards that ensure interoperability on the syntax, communication and transport layers. Most importantly, our study demonstrates that (1) interoperability can only be achieved by combining a full set of standards (i.e. Internet, Web service and industry standards), and that (2) specifying standards for all relevant levels of agreements does not necessarily lead to full interoperability in B2B relationships. It calls for additional design and mapping rules that specify vertical transformation of pragmatic and semantic level constructs onto the Web service interface. Our research also suggests that Web services and SOA will have limited impact on B2B interoperability as long as they are not complemented by additional domain-specific specifications related to semantics and pragmatics.

Our research aims to contribute to the emerging stream of research related to service-oriented concepts in B2B integration. To our knowledge, no other study has investigated the interplay of Web services and industry standards so far. While recent work on interorganizational integration mostly focuses on either technical integration using Web services (e.g., Gosain 2007) or the modelling of business processes (e.g., Hofreiter and Huemer 2006), our research outlines a more comprehensive model that defines a complete set of constructs to cover the necessary semiotic layers of communication. In contrast to existing e-business frameworks, such as ebXML (Hofreiter et al. 2006), our model explicitly describes the translation of business-level constructs into implementation artefacts. As we have seen from the field study, this is necessary to prevent ambiguous Web service designs of the same industry standards and to allow for a semi-automatic transformation of business-level constructs into a Web service design at a later stage. In this sense, our findings support the recent activities by UN/CEFACT to establish a Unified Modelling Methodology (UMM).

Limitations

It is important to mention the limitations of our research due to the fact that validation of our conceptual model was performed in a specific industry setting and made use of a relatively comprehensive industry standard. Since the collaboration of automotive manufacturers and suppliers is characterized by relatively stable B2B processes with high transaction volumes, the specification and implementation of public processes and common information and role models is feasible for both manufacturer and suppliers. It can be argued that our model has to be adapted to other industry settings involving smaller and less IT-savvy enterprises. This might include mechanisms for more dynamic discovery and composition of services like those demonstrated by Fodor and Werthner (2004) for tourism. An inherent limitation of our model for service-based interoperability is the fact that it postulates the physical implementation by means of Web services.

It is also important to mention that our research does not address the many organizational and political issues that characterize the development and adoption of standards. However, we are convinced that accepted design principles for B2B standards would contribute to a more structured way of standards development and eliminate some of the political debates around standards.

Implications for standard development

As an implication of our study, researchers as well as practitioners and standardization bodies should reconsider the role and focus of industry standardization as well
as the methodology and approach for leveraging Web services concepts. Our findings suggest that industry or vertical standardization development should focus on specifying the set of constructs describing semantics and pragmatics. Ideally, industry standards should remain syntax-independent and build on widely accepted service design principles that result from a broad consensus of multiple industry and functional domains. Thus, we support Feuerlicht (2005) who calls for engineering principles and methodologies in B2B standardization as well as recent UN/CEFACT efforts (UN/CEFACT 2006a). A number of positive effects would result if standard development initiatives targeted their efforts at the relevant constructs and followed the concept of service-based interoperability. On the one hand, the efficiency and the quality of results of many standards development processes would increase, since today they rely heavily on the individual skills of their members. On the other hand, companies would become more interoperable across a number of industries and geographical regions since industry standards built on the same design principles and were implemented using standard integration technologies. In this context, it is important to notice that today’s standards neither focus exclusively on the semantic and pragmatic layer, nor comprehensively specify these constructs (Leser 2005).

Our findings also recall that interoperability requires specifications to be even more precise than existing B2B standards are. As of today, companies still need to bilaterally agree on how they interpret and implement the standard, thus reflecting problems related to EDI-based standards (Brousseau 1994, Damsgaard and Truex 2000). On the technical layer, this issue has been solved by WS-I profiles, which have been created to ensure the compatibility of existing implementations of Web service standards and are supported by most software vendors. We conclude that the profiling of industry standards analogous to the profiling efforts by WS-I on the syntactical and communication layer could be beneficial. In the context of vertical standards, profiles should aim to narrow down the many possible interpretations of the standard specification and describe how to implement it using typical integration technologies, namely XML or Web Services. Profiles would comprise detailed guidelines and specifications which ensure unambiguous interpretation of the corresponding business standard as well as conformance rules which allow for testing their organizational and technical implementation.

Implications for research on service-based interoperability

We encourage researchers to enhance the suggested model for service-based interoperability and validate it in other industry settings. In this regard, it would be interesting to explore empirically how the quality and completeness of standards affect the setup costs for B2B system linkages. Our model for service-based interoperability might also serve as a basis for comparing the scope of different industry standards or for analysing the possible strategies of companies in reaction to imperfect standards. Future work is necessary to investigate the use of enhanced Web services concepts, in particular ontologies and process choreography, in order to codify the arrangements on the semantic and pragmatic layers. It might also be worthwhile to further elaborate service interaction patterns, as suggested by Barros et al. (2005) and Endrei et al. (2004), to support consistent service design across multiple domains.

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