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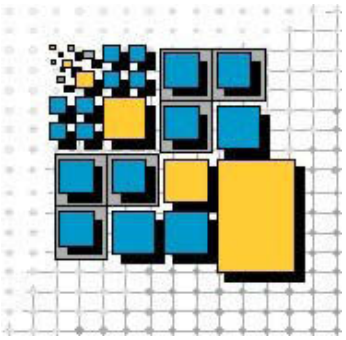

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Due to hardware developments, strong application needs and the overwhelming influence of the net in almost all areas, distributed systems have become one of the most important topics for nowadays software industry. Owing to their ever increasing importance for everyday business, distributed systems have high requirements with respect to dependability, robustness and performance. Unfortunately, distribution adds its share to the problems of developing complex software systems. Heterogeneity in both, hardware and software, permanent changes, concurrency, distribution of components and the need for inter-operability between different systems complicate matters. Moreover, new technical aspects like resource management, load balancing and guaranteeing consistent operation in the presence of partial failures and deadlocks put an additional burden onto the developer.

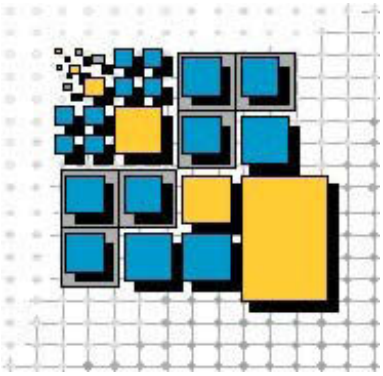
The long-term common goal of our research efforts is the development, implementation and evaluation of methods helpful for the realization of robust and easy-to-use software for complex systems in general while putting a focus on the problems and issues regarding distributed systems on all levels. Our current research activities are focussed on different aspects centered around that theme:

- *Reliable and inter-operable Service-oriented Architectures*: Development of design methods, languages, tools and middle-ware to ease the development of SOAs with an emphasis on provable correct systems that allow for early design-evaluation due to rigorous development methods. Additionally, we work on approaches and standards to provide truly inter-operable platforms for SOAs.
- *Implementation of Business Processes and Business-to-Business-Integration (B2Bi)*: Starting from requirements for successful B2Bi development processes, languages and systems, we investigate the practicability and inter-operability of different approaches and platforms for the design and implementation of business processes with a focus on combining processes from different business partners.
- *Quality-of-Service (QoS) Aspects for SOA and B2Bi*: QoS aspects, especially reliability and security, are indispensable when putting distributed systems into practical use. We work on methods that allow for a seamless observance of QoS aspects during the entire development process from high-level business processes down to implementation platforms.
- *Agent and Multi-Agent (MAS) Technology:* Development of new approaches to use Multi-Agent-Systems for designing, organizing and optimizing complex systems ranging from service management and SOA to electronic markets and virtual enterprises.
- *Visual Programming- and Design-Languages*: The goal of this long-term effort is the utilization of visual metaphors and languages as well as visualization techniques to make design- and programming languages more understandable and, hence, more easy-to-use.

More information about our work, i.e., projects, papers and software, is available at our homepage (see above). If you have any questions or suggestions regarding this report or our work in general, don't hesitate to contact me at guido.wirtz@uni-bamberg.de

Guido Wirtz

Bamberg, January 2010



A Requirements Analysis of Business-To-Business Integration

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Abstract Ever fiercer competition has forced enterprises not only to optimize their own operations but also to cooperate with their suppliers and customers along their supply chains. Thus, competition today usually takes place between supply chains and not between individual enterprises. Business-To-Business integration (B2Bi) is a major task of supply chain management (SCM), and although it already has been researched for years, B2Bi is still an area of active research with a plethora of research questions and according approaches. Hence, management of B2Bi projects necessitates the identification of relevant requirements which is a far from trivial task.

This paper identifies a core set of B2Bi challenges and deduces a comprehensive set of B2Bi requirements that are particularly useful for tackling the challenges identified. The derivation of B2Bi requirements follows an inductive approach that is based on the analysis of integration standards, reference architectures and related literature.

In order to operationalize the B2Bi requirements for further analysis and concrete B2Bi projects, the requirements are classified according to the abstraction layers of a B2Bi schema. Thus, this report not only offers a requirements check list for B2Bi projects but also helps in deciding when to address which requirements during the course of a B2Bi project.

Keywords requirements, business-to-business integration, business process integration, business collaboration

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List of Abbreviations

AS2	Applicability Statement 2
B2Bi	Business-to-Business Integration
BM	Business Model
BPM	Business Process Management
BPM	Business Process Model (in the context of the B2Bi schema)
BPSS	Business Process Specification Schema
CHOR	Choreography
EAI	Enterprise Application Integration
ebBP	ebXML BPSS
ebMS	ebXML Message Service
ebXML	Electronic Business using eXtensible Markup Language
EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
NES	Northern European Subset
PUB	Public Orchestration
PRIV	Private Orchestration
QoS	Quality of Service
RNIF	RosettaNet Implementation Framework
RS	Runtime Systems
SCM	Supply Chain Management
TLS	Transport Layer Security
UMM	UN/CEFACT's Modeling Methodology
UN/CEFACT	United Nations Centre for Trade Facilitation and Electronic Business

1 Introduction

The role of Supply Chain Management (SCM) as a critical success factor for enterprises in today's competitive world is pointed out by many renowned authors, e.g., [LC00] state that *"[...]the ultimate success of the single business will depend on management's ability to integrate the company's intricate network of business relationships[...]."*. [MDK+01] define a *supply chain* as *"a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer."* and identify *Integration of Processes* as one of the core tasks of SCM. The integration of processes is at the core of Business-to-Business integration (B2Bi, cf. [TXW06]) which is the subject of investigation of the work at hand, namely

requirements for the analysis, design, development and maintenance of B2Bi information systems.

The integration of two or more enterprises' processes can be interpreted as the implementation of a single business process spanning multiple enterprises. The tasks throughout the life cycle of a business process, i.e., process design and modeling, system configuration, process enactment and diagnosis (cf. [vdAtHW03]), therefore apply. [vdAtHW03] argue that these tasks are not completely supported by today's business process management systems. B2Bi further raises several specific challenges that range from communication among unequal personnel to homogenization of information systems. Also, there are some generic challenges like comprehensibility or feasibility that gain importance due to the B2Bi setting.
In the face of these challenges, this paper paper develops a comprehensive set of B2Bi requirements in order to facilitate the development and analysis of B2Bi systems. Different types of requirements sources have been analyzed for enhancing both the validity and the completeness of the requirements set. First, the functionality of dedicated integration standards such as ebXML BPSS (ebBP) [OAS06], UMM [UMM06], RosettaNet RNIF [Ros02] and NES [Nor07] has been investigated. Second, reference architectures for B2Bi and business process management (BPM) have been examined. Finally, an extensive literature study has been done.

Two assumptions were made for analyzing these sources:

- Requirements that apply to BPM also apply to B2Bi, and
- functionalities of integration standards have been driven by according requirements.

While the first assumption is justified by interpreting B2Bis as enterprise spanning business processes, the second assumption simply states that integration standards and reference architectures have not been created *accidentally*.

The *set of requirements is classified according to two different systems.*

- First, the *relation between requirements and B2Bi challenges* is investigated, i.e., the contribution of a requirement in addressing a challenge is valuated. This information

helps in adapting the requirements set to different flavors of B2Bi scenarios with varying importance of B2Bi challenges. Also, relations between particular requirements can be identified more easily.

- Second, this paper classifies *each requirement according to a B2Bi schema (cf. figure 1) capturing the abstraction levels of a B2Bi* which may be associated with the phases of software development projects. Consequently, this second classification helps in deciding the question of *when* to consider the respective requirements during a B2Bi project and in identifying the areas and technologies that have to be investigated for solving the requirements.

This B2Bi schema, which is an evolution of the open-edi reference model [ISO04], also narrows down the scope of this work by defining the abstraction levels to be investigated. The schema starts out with the *real world* level that represents the enterprise processes to be integrated. In an idealized world, the *business model* of the integration is first captured which describes the exchange of values between partners on an abstract level [DGWZ07]. This business model is then further refined to a *business process model* that specifies the flow of information and type of interaction among the integration partners [DGWZ07]. The next refinement step leads to the *choreography level* which captures the overall message exchanges of the integration partners. The differences between the latter two models are sometimes fluent but *business process models* typically serve as a communication means between business partners while *choreography models* represent a detailed technical communication specification intended to be processed by machines [SW08b]. Quality-of-Service (QoS) attributes are also frequently introduced for the *choreography model*. The B2Bi schema then foresees the definition of *public orchestrations* to capture the message exchanges of the individual integration partners. The three small rectangles within the *public orchestration* rectangles of figure 1 represent major issues to address on this abstraction level, i.e., the definition of the control flow, the selection of communication standards and the realization of transactions that keep the information systems of the integration partners consistent. Inter-operability and consistency between the *public orchestration* models of the integration partners are of paramount importance. Thus, *public orchestrations* can be interpreted as contracts that define the obligations of each integration partner. In order to simplify analysis and to hide internal details from integration partners the B2Bi schema restrains *public orchestrations* to capture only the externally observable message sequence while the integration with backends is to be specified in *private orchestrations*. Finally, the *runtime systems* level describes the deployment and execution of *private orchestrations*. This covers aspects such as the configuration of endpoint information for accessing backend systems, monitoring *private orchestration* instances and collecting runtime data for analysis techniques like process mining. Note that the actual implementation and management of backend systems as well as organizational aspects of managing runtime systems is not in the scope of this paper.

The B2Bi schema and the requirements found may be applied to different types of B2Bi that have been identified in the literature:

- [GVL+05] identified two basic types of B2Bi, namely extended enterprise integration and market B2Bi. Extended enterprise integration covers relationships of integration partners who know each other and have agreed to do business with each other for an

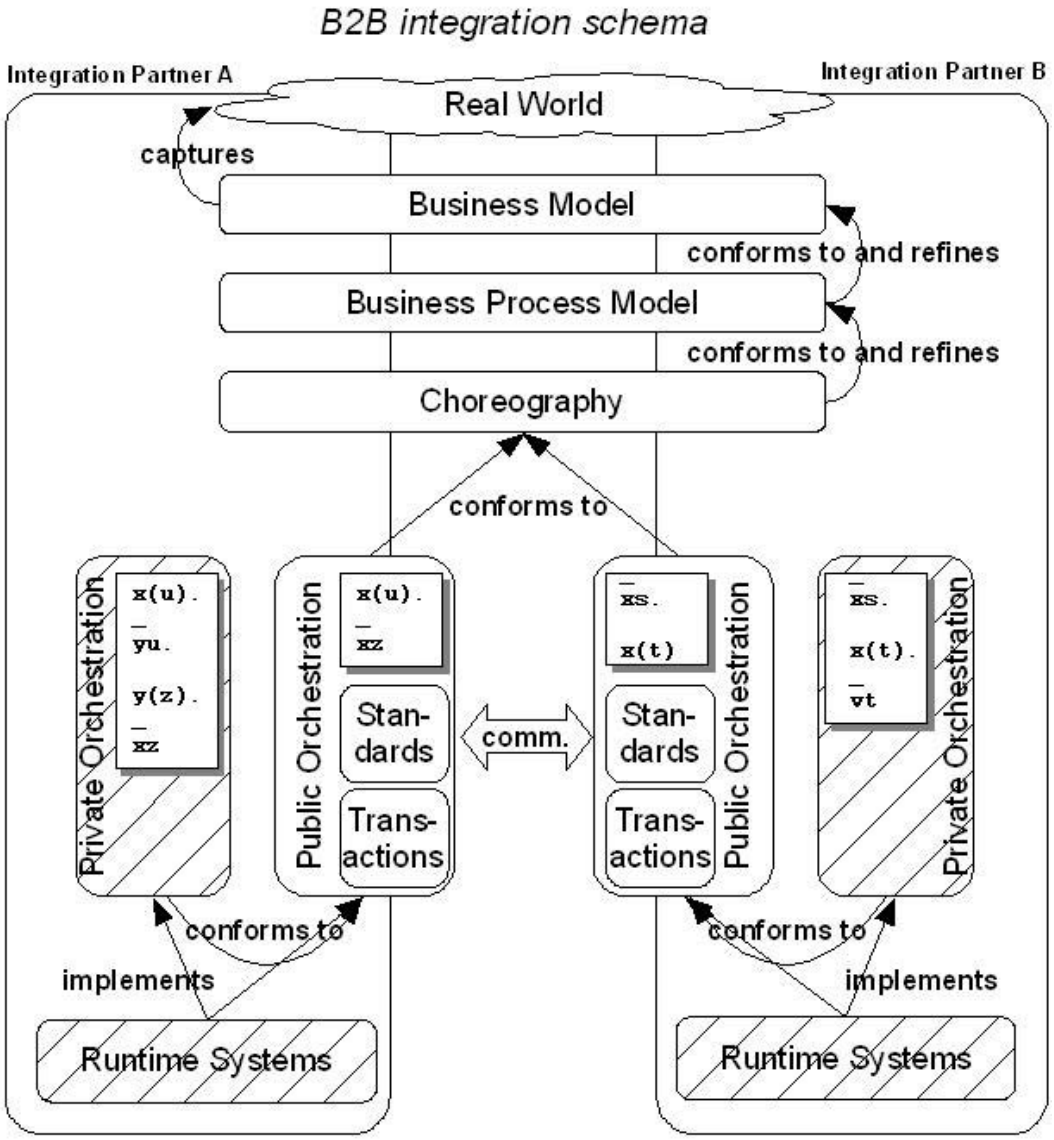

Figure 1: B2Bi schema as defined in [SW08b]

extended period of time ([GVL+05]). They know in advance their partner can provide more or less the necessary services and thus are willing to spend partner-specific IT investments. Opposed to that, market B2Bi covers relationships that do not allow partner-specific IT investments, because, in its extreme form, integration partners do not know each other in advance and potentially choose services from different partners for each transaction. Clearly, the boundaries between extended enterprise integration and market B2Bi are fluent and [GVL+05] find that, currently, *"market B2Bi primarily concerns indirect integration through electronic marketplaces"*.

- [SJH08] identified and evaluated three different strategies for *"cross-organizational service composition"* which may directly be applied to B2Bi. These are *"a highly centralized solution (a central hub allows users to find potential business partners, to collaboratively model service choreographies and to finally execute them)[...,] a hybrid approach (which*

applies a de-central service choreography, but is supported by a central hub) [...and] a fully decentralized, peer-to-peer architecture which works without any central entity." Note that the latter two solutions both use separate orchestration engines for each integration partner, but the hybrid approach employs a central server for, among others, managing data and process templates as well as for collaborative modeling. Finally, [SJH08] propose an event-driven architecture based on the concept of a so-called *event bus* for integration of collaborations with *"a huge degree of variability and complexity"*. The drawback of this solution is that all integration partners are forced to use the proposed *event bus* which servers as kind of a message backbone similar to enterprise service buses.

- [vdAtHW03] classify B2Bi according to the degree of human involvement, i.e., *Straight Through Processing* without human involvement and *Case Handling* with human involvement. The goal of straight through processing is maximum automation and thus reducing costs and cycle times. Case handling pays tribute to the fact that *"many processes are much too variable or too complex to capture in a process diagram"* [vdAtHW03].

Clearly, the importance of the requirements and particularly the valuation of requirement importance depending on the B2Bi schema abstraction layer (as proposed in section 4.2) may vary heavily with the B2Bi type under consideration. Case handling models the intended flow of execution of a case but, if not explicitly forbidden, also allows other flows that skip authorizations or undo activities [vdAtHW03]. Apparently, case handling therefore has more challenging requirements with respect to flexibility or semantic constraint management than straight through processing. Further, [GVL+05] identified that the use of standards or registries such as UDDI [BCvR03] is less important for the extended enterprise integration type of B2Bi than for market B2Bi. Contrarily, other requirements such as security are equally important for each B2Bi type. This is not to be confused with the suitability of different architectural styles for fulfilling particular requirements. Schroth et al. compare the different integration strategies identified in [SJH08] according to several criteria and find that *central orchestration* lends itself better to guaranteeing security than *de-central orchestration without hub*.

Having pointed out the influence that different B2Bi types may have on the applicability of the work at hand, the paper proceeds as follows: The approach taken in analyzing B2Bi requirements is described in section 2. Section 3 analyzes related work in the area and extensively discusses the boundaries of this work. The requirements found for B2Bi are then defined and classified in section 4. Section 5 discusses the results of this work and points out directions for future work and section 6 concludes the paper.

2 Approach

The approach taken for the work at hand is aligned with three main goals. First, a list of B2Bi requirements should be developed that helps researchers in identifying research opportunities and practitioners in evaluating B2Bi projects and tool sets. Second, this list should be comprehensive. Third, the list should be manageable.

The first goal pays tribute to the influence of B2Bi on today's business world and paraphrases the scope of this work (cf. section 3 for a more detailed discussion on the boundaries of the work at hand.). Comprehensiveness leads to the selection of different requirements sources as described below. The third goal, manageability, contradicts comprehensiveness to some extent and leads to the definition of aggregated requirements. To further enhance manageability, the relation between requirements and B2Bi challenges as well as the abstraction layers of the B2Bi schema (cf. [SW08b]) are also examined in more detail.

Three different types of sources are selected for deducing B2Bi requirements, namely dedicated B2Bi standards, B2Bi/Business Process reference architectures and scientific literature. Thus, different views on the same subject of investigation can be consolidated which leads to a more comprehensive treatment of the topic. The rationale behind choosing B2Bi standards is that requirements are driving implementation artifacts. B2Bi standards are, in effect, used for implementing B2B collaborations and thus the investigation of the functionality of these standards leads to B2Bi requirements. Further, B2Bi standards are usually developed by domain experts and, therefore, this type of requirements source also enables access to expert knowledge.
B2Bi/Business Process reference models/architectures are the second type of requirements source selected. Reference models/architectures describe best practice knowledge on which components to select for representing the subject under consideration and on how to relate this components. The *qualities* of such reference models/architectures may be used for evaluation purposes (cf. [LS04]) and define requirements at the same time. Hence, examining the qualities of the components and the relationships among these reveals the intended requirements.
The third type of requirements sources is scientific literature. The following rule is used for eliciting B2Bi requirements from literature: Either the paper contains an explicitly defined requirement or the authors describe some functionality/property/method/concept/tool as particularly useful or not useful. The sheer description of a functionality/property/method/concept/tool without valuation is not sufficient for deducing requirements. For the work at hand, different categories of papers have been searched for. The first category comprises surveys and reviews about requirements for B2Bi. This category is scarcely occupied. Further, B2Bi and BPM surveys are considered. We claim that BPM is tightly related to B2Bi because business collaborations can be interpreted as enterprise-spanning business processes. Third, papers that define requirements for some sub-category of B2Bi and BPM are considered to be relevant. This category comprises topics like Web Service compositions as technique for implementing B2Bi or Enterprise Application Integration (EAI) which is an important BPM task. Finally, drivers and obstacles for adopting B2Bi has been selected as a category of focal publications.
The literature search itself has been performed using scientific search engines like IEEE Xplore[1],

[1] `http://ieeexplore.ieee.org/Xplore/`

ACM Portal[2] or Google Scholar[3] and by systematically searching relevant journals, conference proceedings and institutional homepages.

For eliciting requirements each reference, i.e., B2Bi standard, reference model/architecture or publication has first been evaluated in isolation and all requirements found have been written down separately. This unconsolidated list comprised several hundred requirements which is caused by identical requirements defined in different references and by very detailed requirements lists that can be deduced from some sources such as [OAS06] or [NK05]. Therefore, related requirements have been aggregated, for example 11 consistency requirements identified in [SW08b] have been merged to simply *consistency*, and checked for semantic equivalence by investigating the related references again. Eventually, 78 aggregated B2Bi requirements have been identified. For enabling traceability of the origin of requirements, the related sources have been associated in tables 2 and 3 (pages 33, 36). This matrix not only enhances traceability but also gives an impression of how frequently a requirement is identified. A true statistic analysis is not possible because the sample of requirements sources is necessarily influenced by the background of the researchers and therefore not random.

The classification of requirements according to B2Bi challenges and B2Bi schema abstraction layers has been performed in a two-step process. First, each author of this report, who all are engaged in distributed systems, workflow and business process modeling, classified the requirements individually. Then, the results of individual classification have been compared and merged in several discussion sessions which lead to matrices 4 (page 39) and 5 (page 42).

[2] `http://portal.acm.org`
[3] `http://scholar.google.com/`

3 Related Work

Related work for this work stems from the areas of Business Process Management, Supply Chain Management, Enterprise Application Integration, Information Systems Design, B2Bi and lots of more specialized domains that target specific integrations technologies such as Web Services. The discussion of that work is performed in two steps. First, literature that targets the scope of this report in full or partially is discussed. As pointed out in section 1, the scope of this work is the derivation of requirements for the analysis, design, development and maintenance of B2Bi information systems. In a second step, the research areas that reside on the boundaries of this report's scope are identified.

Considering the first category of related work, the literature identified deviated from our work with respect to scope or with respect to diversity of requirements sources or both. Basically, any of the requirements sources listed in tables 2 and 3 could be cited here. Instead, those publications that come closest to the style of this report are discussed.
[MBB+03] discuss *issues and enabling technologies of Business-to-business interactions*. First, B2Bi interactions are split up in a *communication*, *content* and *business process layer* and, then, *coupling among partners*, *heterogeneity*, *autonomy*, *external manageability*, *adaptability*, *security* and *scalability* are identified as evaluation dimensions. Second, *B2Bi technologies*, *XML-based B2Bi frameworks* and *Web Services*, *Research Prototypes* and *Deployment Platforms* are contrasted with these layers and evaluation dimensions. Finally, some open issues are specified. The work of [MBB+03] is different from ours in offering a less elaborate B2Bi schema and in defining a less comprehensive set of B2Bi requirements where both the evaluation dimensions and open issues identified in [MBB+03] can be considered to define B2Bi requirements. Instead, the authors of that paper concentrate on a more detailed presentation of the technologies/frameworks/prototypes/platforms, but do not use these for gathering requirements.
In [YLBM08], *issues, solutions and directions in deploying and managing Web services* are analyzed. That paper is related to our work in dealing with an important B2Bi implementation technology, but, as B2Bi is not the only application domain of Web Services, B2Bi specific characteristics are not treated comprehensively. Also, the focus of the paper is put more on the analysis of implementation concepts and technologies than on deriving requirements.
[vdAtHW03] survey business process management and therefore are relevant to our work. They define the BPM lifecycle and put important related concepts like Workflow Management, Business Activity Monitoring and Business Process Analysis into context. In doing so, they also identify several important requirements for B2Bi, but they do not derive a comprehensive requirements list nor classify them according to a B2Bi schema.
[ATSK04] present a requirements analysis and design proposal for performing peer-to-peer e-business transactions. That paper focuses mainly on the *market B2Bi* type as identified in [GVL+05] and therefore is not as comprehensive in scope as our work. Also, the authors do not classify their requirements according to B2Bi challenges or abstraction layers.
In [SW08a], the results of a case study in business process management is presented. This comprises a list of requirements that is less comprehensive than the one of this paper. Also, only a single source for requirements, i.e., the case study, is considered for deriving requirements.
An Enterprise Integration (EI) Methodology is described by Lam and Shankararaman in [LS04] and they explicitly declare B2Bi to be a special EI scenario. The focus of that paper are

the envisioned project phases of the integration methodology, but lists of *integration requirements* and *qualities of integration architectures* are also presented. Whereas the integration requirements only deal with issues related to technical communication like response time and volume/throughput, the qualities of integration architectures are boiled down to five abstract qualities like openness and feasibility. Methodologically, that paper is different from ours in using Lam's and Shankararaman's experience in EI projects as requirements source instead of using different types of literature as we do.
Apart from the papers just discussed that have a more or less global B2Bi scope, there are lots of publications that are different from our work in focusing selected aspects of B2Bi or BPM systems, e.g., process modeling languages [LS07], simulation [GPD96], process flexibility [SMR+08] or semantic constraint management [LGRMD08].
Finally, the B2Bi schema taken from [SW08b] (see figure 1) is a source of requirements on its own. In particular the B2Bi schema layers are not explicitly declared to be a requirement, although it is obvious that there is a need for 'business process modeling' (BPM layer) or 'the definition of message exchange between partners'(public orchestration layer). These requirements are not included in our requirements set because they are part of the presentation.

The second step in discussing related work consists of identifying research areas at the boundaries of this work's scope. Note that we explicitly do not target at requirements of these areas. The first area comprises *project management and organizational issues* during performing B2Bi projects. Project management typically comprises tasks like risk management, human resource allocation or project scheduling, while organizational issues cover aspects like cultural fit, implementing organizational change, level of support for IT projects or the analysis of organizational capabilities. Exemplary publications that are dedicated to these issues are [Lam05] investigating EAI success factors or [MA08] defining a capability assessment framework for the adoption of B2Bi Systems. This area is also considered to be important in research work with a different focus like [LC00], [Goe08] or [NK05].
Another neighboring area is the business perspective on B2Bi that drives the design and development of B2Bi information systems. Supply Chain Planning is a major part of the B2Bi business perspective and comprises long-term decisions like the strategic design of an enterprise's supply chain network to mid- and short-term planning tasks like collaborative planning, forecasting and replenishment (CPFR) or master planning. The definition, measurement and monitoring of performance figures also belongs to the business perspective of B2Bi. Clearly, all these tasks heavily influence the functional and non-functional requirements for a particular integration system, but the domain problems themselves first have to be solved using methods of logistics and supply chain management, corporate management and others. These domain problems are discussed, among others, in [PS07] who target inter-domain master planning in supply chains, in [GPM04] who target at performance measures for supply chains and in [SAGS05] who deal with the strategic design of supply networks.
Finally, as the scope of the work at hand comprises the design and development of information systems generic requirements for models and implementations apply. Examples of such requirements are coupling, cohesion, abstraction or reuse. This paper does not attempt to define a comprehensive requirements list for arbitrary models. Instead we're setting out to derive a comprehensive list of B2Bi requirements that can be justified by relevant B2Bi requirements sources.

4 Analysis of Requirements

This section starts out with the identification of seven main B2Bi challenges in section 4.1 that are used as one out of two classification schemes for B2Bi requirements. Apart from providing a classification scheme the B2Bi challenges have also been used for structuring the presentation of B2Bi requirements in section 4.2. There, the association with requirements sources and with the B2Bi schema abstraction layers is presented as well.

4.1 B2Bi Challenges

For B2Bi systems, four original and three derived challenges have been identified that are presented in table 1. The four original challenges immediately emerge from the typical setting of most B2Bi scenarios and cover communication among unequal personnel, agreement, management of complex associations and homogenization of computing resources. Thinking about a simple quote and order scenario with personnel from two different enterprises having to agree upon what data to exchange and when to perform business tasks depending on the message exchanges while considering that a similar process may have to be performed with different business partners using various communication technologies, these requirements become obvious. But, these challenges also come in different flavors. Agreement does not only concern the specification of particular message formats and a business process that reacts to messaging events. It is also a question of legal implications of message exchanges. Similarly, homogenization of computing resources not only concerns differing computing platforms of integration partners and interfacing with legacy systems. It is also about considering the characteristic issues of distributed systems like partial failure and lost/duplicated messages.
The three derived challenges comprehensibility, feasibility and changeability are more generic in nature and therefore also apply to other systems than B2Bi systems. Nonetheless, they have been included as they are particularly challenging in the B2Bi context. Comprehensibility is especially hard in the face of communication among unequal personnel, management of complex associations and homogenization of computing resources, but it is indispensable for achieving agreement. Similarly, feasibility as a second precondition for agreement needs special attention when considering communication among unequal personnel and homogenization of computing resources. Finally, the importance of changeability can be derived from management of complex associations and homogenization of computing resources.
There may be different valid systematizations of B2Bi challenges. The systematization we are presenting here has been developed on the basis of the authors' experience in B2Bi research and further refined during the classification of this work's B2Bi requirements. Eventually, 76 out of 78 B2Bi requirements could be associated with a B2Bi challenge it particularly helps solving which is an indicator for the validity of the challenges scheme.

Table 1 shows the challenges together with the respective variants and relations between original and derived challenges.

Index	Type	Challenge	Variants	derived from	essential for
1	original	Communication among unequal personnel	- Across enterprises - Business analyst to IT expert		
2	original	Agreement	- Legal - Business - Technical		
3	original	Management of complex associations	- Dynamics with respect to *well-known* partners and partner links - Dynamic binding to *unknown* partners - Multi-party collaborations		
4	original	Homogenization of computing resources	- Legacy systems - Platform heterogeneity - Distributed computing		
5	derived	Comprehensibility		1,3,4	2
6	derived	Feasibility	- Business appropriateness - System appropriateness	1,4	2
7	derived	Changeability	- Extensibility - Replaceability	3,4	

Table 1: Overview of B2Bi challenges

4.2 Description of B2Bi Requirements

The B2Bi requirements are presented in the list below (starting on page 12) and in four tables. Tables 2 and 3 (pages 33/36) associate each requirement with sources it has been identified in which enables traceability of our work. Also, depending on the requirements source, this information may be useful for looking up additional context information, different variants of or even solutions to requirements. In case a requirement has been identified in a requirements source according to the rules defined in section 2 the respective cell has been valuated with a "+". When a requirements source only describes some useful features for satisfying a requirement, but does not explicitly associate these features with a requirement or declare the requirement itself, then the according cell has been valuated with a "0". Otherwise, the cell has been left empty.
Table 4 (page 39) defines the contribution each requirement adds to addressing our B2Bi challenges which helps in assessing the importance of each requirement in different B2Bi scenarios that vary with respect to the importance of each challenge. Also, the challenge association is helpful in identifying interrelations between requirements. Clearly, the contribution of fulfilling a particular requirement in addressing a challenge differs from challenge to challenge. For differentiating the level of contribution each of the authors determined the function $ctrb : \text{REQ} \times \text{CHL} \rightarrow \{0, 1, 2\}$ (table 4), where REQ is the set of requirements presented below, CHL is the set of challenges presented above and {0,1,2} represent the level of contribution varying from *no contribution* (0) and *some contribution* (1) to *highest contribution* (2).

In order to find the challenge a requirement contributes most, the constraints

$$\begin{aligned}
\text{C1:} \quad & \forall (a,b) \in \text{REQ} \times \text{CHL}, ctrb(a,b) = 2 : \\
& \nexists (x,y) \in \text{REQ} \times \text{CHL}, x = a \wedge y \neq b \wedge ctrb(x,y) = 2 \\
\text{C2:} \quad & \forall a \in \text{REQ} : \exists (x,y) \in \text{REQ} \times \text{CHL}, x = a \wedge ctrb(x,y) = 2
\end{aligned}$$

had to be respected when creating the relation saying that for each requirement exactly one challenge shall be assigned the contribution value 2. In so far, the contribution values for a given requirement depend on each other and therefore the contribution values for two different requirements cannot be compared (therefore the term "highest contribution" has been chosen). The authors' relations then have been discussed and merged in several meetings which lead to the result presented in table 4 on page 39. Constraint C1 is satisfied for each requirement except for requirement 13 (Control flow definition) where both the *feasibility* and the *agreement* challenge have been valuated with 2. Constraint C2 is satisfied for each requirement except for requirement 78 (formal methods) for which no challenge could be found that benefits substantially more from requirement 78 than the other challenges.

Finally, table 5 (page 42) associates each requirement with the abstraction layers of our B2Bi schema (figure 1). This information is helpful for identifying the problem domains affected by a requirement and available solution technologies. Also, as these abstraction layers correlate with software development phases this classification helps in deciding when to consider a requirement. The degree to which a requirement shall be considered on abstraction layers has been specified by the function $csdr : \quad \text{REQ} \times \text{CHL} \rightarrow \{\%, -, 0, 1, 2\}$ (table 5), where REQ is the set of requirements presented below, CHL is the set of challenges presented above and {%,-,0,1,2} represent the degree of consideration varying from *not applicable*(%), *should not be considered*(-), *could be considered*(0) and *should be considered*(1) to *is strongly recommended to be considered*(2). Again, each author first determined *csdr* individually before the final function presented in table 5 has been merged during several meetings.

The description of B2Bi requirements is aligned with the challenges classification, i.e., for each challenge c all requirements r with ctrb(c,r) = 2 are described. For additional help in identifying interrelations among requirements, the presentation of the requirements is further structured by bundling them to *abstract* requirement groups, e.g., requirements 1 (Language participant language knowledge appropriateness) and 2 (Intelligible feedback of analysis) have been bundled within the requirement group *Use specific media that help*. These groups are the result of the authors' analysis and have not explicitly been declared in the sources investigated. In so far, they are not directly backed by the requirements sources.

The actual requirements are then presented per group. Each requirement carries two index numbers. The first index number corresponds to the order of requirements after having performed the challenge classification as shown in table 4. Also, this index number can be used for looking up each requirement in table 5. The second index number represents the sequence in which the requirements have been identified in the requirements sources. This index number is to be used when performing a lookup in tables 2 and 3. In the following list, the abbreviations BM, BPM, CHOR, PUB, PRIV and RS refer to the B2Bi schema layers presented in figure 1.

Challenge: Communication among unequal personnel

Group: Use specific media that help

Req. (1;58): Language participant language knowledge appropriateness

The first requirement demands that a language for describing B2Bi artifacts like business models, business process models and choreography models should be accessible for the participants of a B2Bi project. This requirement was originally found in [NK05] that defines a *quality framework* for business process models. The participant appropriateness can be assessed, for example, by checking in how far the language uses terminology of the project domain or whether the level of abstraction is adequate. Similar demands have also resulted from performing a case study [SW08a] and the analysis of business process models [Pha98, PS00] and [GPD96].

Note that *csdr*-value of this requirement for public and private orchestrations is 0 because, typically, rather general purpose languages are used by IT experts for describing message exchanges at these layers.

Req. (2;52): Intelligible feedback of analysis

This requirement has first been found in [LGRMD08] that is concerned with constraint management in process models. It can also be derived from [GPD96] that analyzes the use of simulation for process modeling.

Meeting this requirement is not only relevant for the BM and BPM layer, but also for the RS layer to give operators the possibility to detect and trace execution errors sensibly.

Group: Describe context of application

Req. (3;77): Documentation

Documentation is a rather general requirement that is not always explicitly formulated in related requirements sources, but can be derived from several B2Bi standards like [OAS05a, OAS05b], [UMM06], [Nor07] and [Ros02]. Also, [GPD96] considers documentation to be necessary for applying simulation to business process models.

Consistently, the *csdr*-values are high for each B2Bi schema abstraction layer. Alone the PUB and PRIV layers are valuated with 1 because documentation may **partially** be replaced by conformance checking means.

Req. (4;46): Description of usage scenarios

Description of usage scenarios is useful for business analysts and IT experts in determining common and exceptional behavior and has been postulated in [UMM06], [Nor07], [Ros02], [GPD96] and [Bec96].

Basically, this requirement is particularly important for abstraction layers with a high degree of modeling freedom. Consistently, we consider it to be more important for the PRIV layer than the PUB layer because accessing backend systems like ERP systems (PRIV layer) requires more design choices than simply determining the public message exchange (PUB layer) that may be derived from the CHOR layer to a large extent.

Req. (5;47): Description of business requirements

Satisfying this requirement derived from [Nor07] and [Ros02] is crucial at the early phases of B2Bi projects and is different from requirement 4 in limiting the design choices for developing B2Bi systems. This may include the natural language specification of pre-/post-conditions of task executions.

Taking care of this requirement at lower abstraction levels (CHOR, PUB, PRIV, RS) is not

considered to be particularly useful as these layers are supposed to specify the technical realization of business requirements and not to define these.

Req. (6;48): Description of business benefits
This requirement has been discovered in [Nor07] and specifies which goals are to be achieved by a particular system at an abstract level. This may be useful when business requirements and usage scenarios are not as comprehensive and precise as they should be. This requirement is similar to requirements 4 and 5 and therefore gets high *csdr*-values for the abstract B2Bi schema layers only.

Group: Group processes together

Req. (7;28): Classification of processes
Classifying processes means building groups of processes according to some criteria where these criteria may vary from B2Bi scenario to B2Bi scenario. This requirement has been detected in the following B2Bi standards: [OAS05a, OAS05b], [UMM06] and [Ros02].
Distinguishing groups of processes is important when it comes to specify the BM and BPM layer, but also for the RS layer for giving operators a means to tailor monitoring and error escalation routines.

Req. (8;29): Definition of associations between processes
This requirement discovered in [OAS05a, OAS05b] and [Nor07]is related to requirement 7, but particularly demands investigating the relations between individual processes in more detail. This may affect commonalities in goals/constraints as well as temporal, data and interface dependencies.
Apparently, this requirement deserves high *csdr*-values for the BM and BPM layer, but it is as important for the PRIV and RS layer. Most B2Bi projects do not develop completely new business processes. Instead, the existing processes of enterprises are connected. Connecting these existing processes using B2Bi systems is all about managing associations. Also, administrating runtime systems is not possible without knowing how the modification of processes affects other processes.

Challenge: Agreement

Group: Define synchronization constructs

Req. (9;2): Support for business transactions
The concept of business transactions is explicitly defined in several B2Bi standards ([OAS06], [OAS02], [UMM06], [Ros02]) with only slightly varying semantics. A business transaction defines the exchange of one or two business documents together with accompanying control messages (business signals) and Quality-of-Service attributes in order to achieve mutual agreement in the face of distributed computing. As such, business transactions are vital for synchronizing the state of B2Bi participants and the concept of atomic execution is at least desirable. The requirement of such a concept can also be derived from the following standards to some extent: [OAS07] and [Nor07].
As this requirement concerns the exchange of messages between integration participants, the CHOR, PUB and PRIV abstraction layer are the first ones to look at whereas such a concept does not make sense at the BM layer.

Req. (10;3): Support for business signals
Business signals are messages that are needed for controlling the exchange of business

documents, but they do not carry business content themselves. Examples for such control messages are so-called ReceiptAcknowledgements or AcceptanceAcknowledgements that signal the successful execution of processing steps like schema/sequence validation or business entity dereferencing. Such messages are explicitly defined in the following standards: [OAS06], [OAS02], [OAS07], [UMM06] and [Ros02]. Note, that these control messages typically have nothing to do with transport level messaging issues like the implementation of reliable messaging.
Due to the close relationship with requirement 9, this requirement is valuated similarly.

Req. (11;5): Support for binary collaborations

Again, the concept of binary collaboration is explicitly defined in several standards ([OAS06], [OAS02], [UMM06], [Nor07]) and denotes the composition of several business transactions within a particular process between exactly two partners. The need for such a concept can also be derived from [Ros02], although the composition of business transactions is not defined there. The focus of binary collaborations is put on enabling complex sequences of interactions for synchronizing the state of two partners so that this requirement received the *ctrb*-value 2 for *agreement* as opposed to requirement 21 (Support for multi-party collaborations) that targets more on *complex associations*.
Sequences of interactions are about defining processes. Consequently, the *csdr*-values are highest for the BPM, CHOR and PUB layer.

Req. (12;7): Support for business documents

The definition of message formats for business documents as well as the meaning of their content is vital for almost any B2Bi process. Support for business documents may also comprise mechanisms for importing/reusing existing document definitions and for managing different versions of business documents. This requirement can be detected in most B2Bi standards ([OAS06], [OAS02], [OAS07], [UMM06], [Nor07], [Ros02]), in scientific publications ([NK04], [SW08a], [BtH98]) as well as in integration architectures ([Bec96], [Kru96], [Sim05]).
Business documents affect more business oriented tasks like defining the meaning of message exchanges/contents as much as more technical tasks concerning parsing and mapping message contents. This leads to high *csdr*-values at all B2Bi schema layers except for the BM layer.

Req. (13;9): Control flow definition

Unless B2Bi processes are very simple, control flow definition using typical control flow constructs like AND/OR-Fork and AND/OR-JOIN is inevitable and has extensively been investigated by the scientific community, e.g., [vdA98], [KtHB00] and [vdAtHKB03]. As a consequence, this requirement can be detected in B2Bi standards ([OAS06], [OAS02], [UMM06], [Nor07], [Ros02]) as well as scientific literature ([NK04], [WvdAD+06], [YWL04], [BtH98]) and integration architectures ([Bec96], [Kru96], [Sim05]). This requirement is the only one for which the authors could not satisfy constraint C1 because ensuring compatible control flow definition in a distributed setting (agreement) is considered to be as important as defining control flow at all (feasibility).
The BPM, PUB and PRIV layer are the main layers for B2Bi control flow definition so that these have the highest *csdr*-values whereas the CHOR layer is more of a technical refinement of the BPM layer so that the *csdr*-value is set to 1.

Group: Describe state space of collaboration

Req. (14;53): Language for semantic constraint specification
This requirement is explicitly defined in [LGRMD08] that demands a language for semantic constraint specification as means for validating, enacting and managing constraints. In an ideal world, such a language would have a formal semantics for facilitating advanced analysis features. Constraints are not only useful for defining constraints during the initial definition of a process, but also come in handy when processes have to be modified at design time or even at runtime by users. This requirement can also be derived from [DW06] and to some extent from B2Bi standards that suggest the definition of pre/post-conditions ([OAS06], [UMM06], [Nor07]).
This requirement is important throughout all B2Bi schema layers, but should particularly be dealt with at the more abstract layers that have the biggest freedom with respect to design decisions.

Req. (15;68): Data oriented process definition
Many B2Bi processes are driven by the data that is exchanged between integration partners (see requirement 12). Consequently, it should be possible to define routing rules based on the data being exchanged and to define how data is transferred, where it is visible and the like (cf. [WvdAD+06]). This requirement is backed by [WvdAD+06], but also by B2Bi standards that define facilities for dealing with data ([OAS06], [UMM06], [Nor07], [Ros02]).
As this requirement is about process definition, the process related B2Bi schema layers are most affected where the PRIV layer has a higher *csdr*-value than PUB because coupling the exchange of business messages with existing backend systems is a particularly hard B2Bi problem.

Req. (16;49): Pre/Post-conditions of process/task executions
This requirement (detected in [OAS06], [UMM06], [Nor07], [Ros02], [LGRMD08], [BtH98]) is related to requirements 5 (Description of business requirements) and 14 (Language for semantic constraint specification). The definition of pre/post-conditions of process/task executions is one option for specifying business requirements. In the requirements sources, such conditions range from high-level, e.g., "two integration partners *know* each other", to concrete, e.g., "a document has been schema-validated". This range distinguishes this requirement from requirement 14 that targets at automatic evaluation of constraints.
This range also leads to high *csdr*-values not only for the BPM and CHOR layer but also for the RS layer.

Group: Allow for partner specifics

Req. (17;16): Integration partner binding
Integration partner binding (identified in [OAS02], [OAS07]) demands to provide a means for identifying integration partners in a technical sense. Such identification data is the basis for attaching partner tailored configurations, e.g., messaging exchange characteristics. The technical orientation of this requirements leads to high *csdr*-values for the PRIV and RS layer.

Req. (18;19): Negotiation of business capabilities
A B2Bi system connects autonomous enterprises. Although the market position of some enterprises heavily influences the scope for decision-making of their integration partners, the detailed business services consumed/provided have to be specified. This requirement has been postulated by [ATSK04] for peer-to-peer scenarios and by [LS04] for enterprise

integration. It can also be derived from integration standards: [OAS02] and [Ros02]. The scope of this requirement leads to high *csdr*-values for the BM and BPM layer.

Req. (19;20): Negotiation of communication capabilities

Once the services to be consumed/provided have been fixed the communication means for exchanging information have to be defined. This concerns the communication technology, e.g., Web Services, ebMS ([OAS07]), or AS2 ([MD05]), as much as the configuration of messaging endpoints and further technologies for implementing Quality-of-Service attributes like encryption or reliable messaging. This requirement has been discovered in integration standards ([OAS02], [Ros02]) as well as in scientific literature ([ATSK04], [YWL04]).
While the focus of communication capabilities is technical, negotiation needs all partners to communicate. Therefore, this requirement should mainly be targeted at the CHOR and PUB layer.

Challenge: Management of complex associations

Group: Allow for unknown partners

Req. (20;56): Reputation information management

This requirement is relevant for integration scenarios with unknown partners. Reputation information management is a means to establish and maintain trust which is indispensable for doing business. None of the investigated integration standards defines concepts for enabling reputation information management which indicates that the majority of current B2Bi projects are performed between more or less *well-known* partners. The requirement has been found in [ATSK04] that explicitly targets at peer-to-peer scenarios.
This requirement concerns all B2Bi schema abstraction layers, from the BM layer that defines whether interaction with unknown partners are acceptable to the RS layer that has to support reputation information management technology.

Group: Define constructs for complex interactions

Req. (21;6): Support for multi-party collaborations

Support for multi-party collaborations is related to requirement 11 and the relationship already has been discussed there. This requirement has been derived from the integration standards [OAS06], [OAS02] and [UMM06]. In these standards, a multi-party collaboration is created by defining the control flow between binary business transactions. A true multi-party collaboration is different from the composition of multiple binary collaborations in which an integration partners processes information/goods of a supplier and hands these on to a customer. In a true multi-party collaboration the interaction takes place with more than one partner that are all either upstream or downstream the supply chain. Such interactions are conceivable for, among others, shipping scenarios but note that despite all integration partners may exchange information/goods the legal implications are typically dealt with on a bilateral basis.
This interaction-centric requirement receives the highest *csdr*-values for the BPM, CHOR and PUB layer.

Req. (22;11): Role modeling

Role modeling is a major tool for specifying functionality in an abstract manner that then can be bound to concrete integration partners. This requirement arises, among others, in the context of defining standard process templates or when publishing/searching integration functionality in registries. Due to its importance, this requirement has been detected

in several B2Bi standards ([OAS06], [OAS02], [OAS07], [UMM06], [Nor07], [Ros02]) and scientific publications ([YWL04], [Pha98], [PS00]) as well as in integration architecture [Bec96].
The definition of roles is more important for layers that do abstract from the concrete implementation. Therefore, the BPM and CHOR layer receive the highest *csdr*-gradings.

Req. (23;12): Role mapping
Role mapping denotes the mapping of abstract functionality to concrete implementations/instances as well as the mapping of roles to other roles. While the former case is a common task in software engineering the latter one is explicitly defined in [OAS06], [OAS02], [OAS07], [UMM06]. For example, a business collaboration may define the execution of a business transaction multiple times. This necessitates the possibility to map a collaboration role, say a buyer, to a business transaction role, say the sender of a purchase order.
The different flavors of role mapping lead to high *csdr*-values for the BPM, CHOR, PUB and PRIV layer.

Req. (24;67): Control flow patterns
Control flow patterns capture frequently needed interaction scenarios. A frequently used collection of control flow patterns is [vdAtHKB03] that has been used together with further patterns by [WvdAD$^+$06] for analyzing the suitability of BPMN for business process modeling. Similar analyses should be performed for assessing process definition languages for the other layers of the B2Bi schema (and already have been performed, e.g., [WvdADtH03]). Accordingly, the highest *csdr*-values are given to the BPM, PUB and PRIV layer.

Group: Overcome technical communication obstacles

Req. (25;17): Flexible configuration of transfer/transport protocol
It is unrealistic to assume that all business partners an enterprise interacts with will manage to agree on a particular configuration of a communication technology. Instead, they probably will even use different communication technologies like AS2, ebMS or Web Services. Also, communication endpoints typically need partner specific configuration. Consequently, the need for flexible configuration of transfer/transport protocols has not only been identified in [NK04] and [Sim05], but also cared for in the following integration standards: [OAS02], [OAS07], [Ros02].
This requirement mostly concerns the CHOR and PUB layers where the communication configuration has to be specified and used as well as the RS layer that has to perform communication according to these specifications.

Group: Manage associations

Req. (26;27): Metadata definition
This requirement has been derived from scientific papers ([ATSK04], [DW06]), from B2Bi standards ([OAS05a, OAS05b], [UMM06] and [Ros02]) and from integration architecture [Kru96]. Metadata definition may serve various purposes ranging from detailed information for implementation to the dynamic discovery of processes/services. In general, metadata may also be intended for human users, but the requirements sources indicate a rather technical use and human-readable metadata is covered by requirements 3 to 6.
This requirement should no be completely neglected on any B2Bi schema layer, but it is particularly important for the CHOR and PUB layer that deal with the technical specification of communication and the selection of services.

Req. (27;30): Cataloging of processes

Cataloging of processes is a requirement that builds upon requirement 26 as the definition of metadata is part of defining a catalog. Additionally, indexes for efficient access to processes/services are to be set up using this metadata. The main sources for this requirement are the ebXML registry standards [OAS05a, OAS05b], but it can also be derived from [Ros02].

Efficient access to processes/services is a benefit for any B2Bi schema layer (except for the BM layer), but lookup at runtime is the most important use case so that the RS layer is valuated with the *csdr*-value 2.

Req. (28;36): Event propagation

Event propagation is well-known from middleware systems and denotes the concept of signaling state changes of nodes to other nodes that may have registered for particular types of events. This concept may also be applied to governance tasks by signaling modifications of process descriptions. This requirement has been detected in B2Bi standards ([OAS05a, OAS05b]) as well as in scientific literature ([YWL04], [DW06]).

The *csdr*-values for this requirement are aligned with its main application domain (RS) but also with its extended use for propagating process definition modifications.

Req. (29;74): Semantic description to support dynamic service discovery and invocation

This requirement derived from [YWL04] describes the completely dynamic discovery and invocation of previously unknown services of unknown partners according to semantic description that captures needed functionality and QoS parameters. This is different from performing registry lookups for services that have a well-known type and that are offered by well-known partners.

Completely automatic lookup of functionality is clearly an issue of the RS layer but it also affects the CHOR and PUB layer that define how functionality is consumed.

Req. (30;25): Registry functionality

A registry is a container for storing metadata about processes, services, integration partners and the like. The functionality of registries greatly varies. In the simplest case, registries only offer lookup by name, but lookup by several criteria up to advanced semantic lookup are possible. Also, registries may offer notification and validation services for informing about process/service changes and ensuring the correctness of registered objects. In the B2Bi setting, such advanced registries may be used to manage associations between integration partners and offer a useful point of control for performing governance tasks. The requirement has been discovered in B2Bi standards ([OAS05a, OAS05b], [UMM06]) as well as in scientific publications ([ATSK04], [DW06]).

Due to the broad range of use cases that may require registry functionality, the *csdr*-values are high throughout all B2Bi layers (except for BM).

Req. (31;26): Repository functionality

Compared to a registry (requirement 30), a repository stores actual artifacts and not metadata about artifacts. This is in line with [OAS05a, OAS05b], but a repository is also frequently considered to be an integral part of a registry or the other way round. In so far, this requirement is very closely related to requirement 30. Apart from B2Bi standards [OAS05a, OAS05b] this requirement can also be derived from scientific publications ([ATSK04], [SW08a], [DW06]) and integration architecture [Sim05].

As the notion of repository used here is about storage of artifacts the highest *csdr*-values are given to the CHOR, PUB, PRIV and RS layer.

Group: Use association management facilitators

Req. (32;54): Semantic constraint management
This requirement is extensively discussed in [LGRMD08] and also identified in [SW08b]. Requirement 14 already demands a *language for semantic constraint specification*, but constraint management takes the declaration of semantic constraints one step further by also requiring the management of constraints throughout the lifecycle of business processes. This comprises tasks like the specification of constraints, validation of constraints, adaptation of technology-agnostic constraints to platforms as well as monitoring and exception handling.
As constraint management affects the life-cycle of business processes, the *csdr*-values are high for all abstraction layers (except for the BM layer).

Req. (33;14): Support for process version control
Version control is an important and ubiquitous concept of software engineering and therefore is important for B2Bi as well. Apart from this general finding, B2Bi has special requirements in terms of managing different versions of processes for different partners. Accordingly, this requirement can be detected in B2Bi standards ([OAS06], [OAS02], [OAS05a, OAS05b], [UMM06]) as well as scientific literature ([SW08a], [DW06]).
This requirement has high *csdr*-values for all abstraction layers that deal with process descriptions and related artifacts.

Req. (34;70): Usage of standards
Standards define common formats, protocols, concepts and terminology. This facilitates communication among partners and reduces the maintenance cost for information systems. In the B2Bi domain, communication technology and business document standards play an important role in limiting the number of interaction variants. This requirement could be derived from any B2Bi standard because the natural purpose of creating a standard is its use. Therefore, these standards are not cited explicitly here. Instead, scientific literature is cited that defines the need for standards: [SW08b], [vdAtHW03] and [SW08a].
Due to its ubiquity, all B2Bi schema layers receive high *csdr*-values.

Req. (35;40): Data formats and data codes
Data formats and data codes are tightly related to requirement 34 (usage of standards) as business document standards essentially define data formats. This requirement is worth mentioning on its own because any B2Bi system needs reasonable support for representing information, but not every data format and data code definition is a standard. Nonetheless, this requirement can be derived from scientific literature ([LS04], [Lam05]) as well as from B2Bi standards ([Nor07], [Ros02]).
Data formats and data codes are a technical issue and therefore deserve more attention on the more technical abstraction layers CHOR, PUB, PRIV and RS.

Req. (36;43): Ease of maintenance
Ease of maintenance is a general requirement of systems management, but it deserves special attention in the B2Bi domain due to the multitude of B2Bi links and configuration sets an enterprise has to deal with. This requirement is backed by [OAS05a, OAS05b] and [Nor07].

Ease of maintenance does not apply to the BM layer because the number of artifacts to manage at this layer is low. On the other hand, the requirement is tough at the PRIV layer where it comes to integrating changes in the public message exchanges/backends with the backends/public message exchanges.

Challenge: Homogenization of computing resources

Group: Deal with basic distributed interaction styles

Req. (37;78): Asynchronous and synchronous interaction

The differentiation between asynchronous and synchronous interactions is well-known from distributed computing and allows for supporting different types of scenarios. Synchronous interaction assumes a communication partner to offer an endpoint for communication at a well-known time (or permanently) and therefore enables immediate processing of requests. Asynchronous interaction temporally and spatially decouples the consumption and provision of services by buffering messages. In the B2Bi domain, both interaction styles can be found, e.g., large enterprises may offer permanent communication endpoints for synchronous interactions whereas requests to small enterprises may be stored in some message inbox until consumed. Note that the differentiation may be applied at different layers of a communication protocol stack. For example, a message may be exchanged using a synchronous communication technology like Web services and then be stored in a buffer before consumed by an application. Similarly, a requestor of a service may transmit a message using an asynchronous communication technology like message queuing and then stop processing until a reply arrived. B2Bi systems are distributed by nature and therefore this requirement is backed by numerous sources: [OAS06], [OAS02], [OAS07], [OAS05a, OAS05b], [UMM06], [Ros02], [YWL04], [BtH98].

Although the style of interaction may affect the BPM layer as well, the main layers for tackling this requirement are the PUB and PRIV layer.

Group: Deal with distributed communication

Req. (38;8): Quality of service

QoS are frequently defined as quantifiable, non-functional aspects of a service, especially network performance attributes. This is not enough for B2Bi because qualities such as encryption and reliability are vital to the exchange of sensitive information but hard to quantify. Therefore the more general definition of [DLS05] is adopted: *"[...]the term QoS [...is] used to denote all non-functional aspects of a service which may be used by clients to judge service quality."*. The importance of this requirement is underlined by numerous requirements sources: [OAS06], [OAS02], [OAS07], [OAS05a, OAS05b], [UMM06], [Nor07], [Ros02], [ATSK04], [OMB07], [LS04], [YWL04], [DW06], [BtH98] and [Sim05].

The highest *csdr*-values have been given to those abstraction layers that implement and specify in detail QoS attributes.

Req. (39;10): Exception/Error handling

A characteristic property of distributed systems is partial failure, i.e., only a subset of participating systems fails/crashes, and communication failures like lost/duplicated/delayed messages. B2Bi systems are a special type of distributed systems where errors may also emerge from the problem of aligning the different views of integration partners and managing a large amount of different B2Bi links. All these factors necessitate the need for adequate exception/error handling which is backed by B2Bi standards ([OAS06], [OAS02],

[OAS07], [UMM06], [Nor07], [Ros02]) and scientific literature ([LS04], [YWL04], [BtH98]) as well as integration architectures ([Kru96], [Sim05]).
While exception/error handling has to be defined on more abstract B2Bi schema layers, the actual detection and troubleshooting takes place at the implementation centric layers so that the *csdr*-values for the PRIV and RS layer are even higher than for the BPM, CHOR and PUB layers.

Req. (40;23): Message correlation
The need for business collaborations (requirements 11 and 21) implies that processes have to be used to bundle related activities. Apparently, there may be several process instances that are active in parallel and therefore the messages exchanged between integration partners have to be correlated with the matching process instance either by offering separate communication endpoints or by including correlation information in the messages exchanged. This requirement can be derived from B2Bi standards ([OAS07], [Ros02]) and scientific literature ([NK04], [YWL04]).
The core abstraction layer affected by this requirement is the PUB layer.

Req. (41;24): Communication interface
A communication interface describes the types of messages, operations and pre-/post-conditions an application can use for submitting/retrieving messages to/from a communication subsystem. Although the need for such specifications is obvious, none of the investigated standards defines a communication interface. Instead, protocol requirements and abstract actions are defined for not tying a communication protocol to a particular platform.
This requirement's focus is technical and therefore the highest *csdr*-values are assigned to the PUB, PRIV and RS layers.

Group: Manage state space

Req. (42;42): Consistency
The IEEE glossary of software engineering terminology [IEE90] defines consistency to be "*The degree of uniformity, standardization, and freedom from contradiction among the documents or parts of a system or component.*" In the B2Bi domain, consistency comes in different flavors, for example the consistency between orchestration models and choreography models is denoted conformance whereas the consistency of interacting interfaces is called compatibility. An overview of important B2Bi consistency requirements is given in [SW08b]. Apart from that, this requirement can be found in [LGRMD08] and in all B2Bi standards that have been investigated.
As consistency is a core issue throughout the whole lifecycle of B2Bi projects, all B2Bi schema layers deserve high *csdr*-values.

Req. (43;55): Semantic constraint violation traceability
This is a special requirement detected in [LGRMD08] that demands correlating constraint violations and modifications of semantic constraints with the result of process executions. While the specification and modification of constraints is an issue of the more abstract B2Bi schema layers the correlation with execution results is particularly hard at the RS layer so that the highest *csdr*-value 2 only is assigned to RS.

Group: Deal with heterogeneity

Req. (44;21): Configuration data for runtime systems

This requirement is related to requirement 17 (Flexible configuration of transfer/transport protocol) and demands to provide manageable formats for configuring runtime systems according to the needs of a particular B2Bi link. Such data reduces the need for manual intervention and hence facilitates dealing with heterogeneous systems. This requirement has been derived from the B2Bi standards [OAS02], [OAS07] and [Ros02].
Being a strongly technical requirement, this problem is to be addressed at the PRIV, PUB and RS layers only, but not at all at the BM and BPM layers.

Req. (45;22): Interfacing with backend systems

Interfacing with backend systems denotes the problem of designing the integration of public message exchanges with internal systems in terms of message types, QoS and interaction protocols and has been detected in [SW08a], [Lam05], [Sim05] and to some extent in [OAS07] that defines abstract message service handler, consumer and producer roles. Note that this requirement is substantially different from defining the interaction protocol between integration partners because internal message formats are not as constrained as message formats for partner messages and the computing environment may be much more safe. For example, the integration processes and backend systems may be hosted in a single computing center where reliable communication media and advanced monitoring solutions are available.
The integration of public orchestrations with backend systems is the natural task of the PRIV abstraction layer so that it is assigned the *csdr*-value 2.

Challenge: Comprehensibility

Group: Decompose problem

Req. (46;1): Multi-level and multi-view description

Describing a problem domain at multiple levels and from multiple views is a basic concept for decomposing problems and thus enabling comprehension of complex scenarios. This is particularly true for B2Bi systems. Note that the B2Bi schema on page 3 is essentially composed of several layers for being able to focus the system at different abstraction levels. At each level, the modeling object may be analyzed from different viewpoints, e.g., separate views for specifying business message types and the control flow may be created. Such an approach enables concentrating on isolated aspects within individual views while contrasting different views with one another helps in detecting inconsistencies. This requirement is backed by numerous requirements sources: [SW08b], [vdAtHW03], [SW08a], [LS04], [Pha98], [PS00], [BtH98], [UMM06], [Ros02], [Bec96], [Kru96] and [Sim05].
This is a general requirement for abstraction layers that deal with modeling and therefore deserves high *csdr*-values except for the RS layer that focuses on executing models.

Req. (47;4): Hierarchical decomposition; Composability

This requirement is different from requirement 46 in not dealing with different levels or views on the same system, but with the relation of an overall model and its more manageable parts. Hierarchical decomposition and composability denote different approaches that lead to the same result, where the former starts with a complex model and decomposes it in more manageable parts and the latter starts with manageable parts and composes a complex model from that. A good example for that is the composition of business collaborations from other business collaborations and business transactions as described in [OAS06] and [UMM06]. This requirement can also be derived from [OAS02], [YWL04],

[GPD96], [BtH98], [Bec96], [Kru96] and [Sim05].
This requirement is considered to be a major issue at the BPM, CHOR, PUB and PRIV layers.

Group: Use adequate representations

Req. (48;37): Visual representation
B2Bi projects need the domain knowledge of business analysts and business modelers who may not be very experienced in modeling processes or systems. Also, business personnel is typically not as trained in reading machine-processable models or even formal representations of models as IT experts are. Visual models help in comprehending complex scenarios faster and therefore facilitate the communication between IT and business personnel as well as individual analysis of models. This requirement can be derived from [ZMW09] and [UMM06] that define visual representations of business collaborations. Also, this requirement can be detected in [Nor07], [Ros02], [Pha98], [Bec96], [Kru96] and [Sim05] and also in the textual standard [OAS06] that supposes to use BPMN [Whi09] for visualizing ebBP.
Visual models clearly are helpful at any abstraction layer, but are particularly necessary at the BPM layer where business personnel from different companies have to align their understanding.

Req. (49;39): State-based modeling
A core task of business process integration is changing the state of the integration partners' systems by performing message exchanges. Consequently, the relation between message exchanges and state changes (as representation of collaboration progress) should be modeled explicitly which is proposed in [PSW09]. This requirement can also be detected in [UMM06], [NK05] and [YWL04].
State-based modeling is particularly useful for reasoning about the effect of (un-)successful message exchanges and therefore the *csdr*-value of the BPM layer is set to 2.

Req. (50;44): Ease of explanation
The demand for models that are easy to explain is very general but deserves special attention in the B2Bi domain due to the need for communication among unequal personnel. This requirement is explicitly postulated in [Nor07] but can also be discovered in [Pha98]. This requirement has to be considered at all layers that deal with models but particularly at the BPM layer that is used to achieve agreement among business personnel of different enterprises.

Req. (51;59): Language comprehensibility appropriateness
[NK05] present a framework for assessing the quality of business process modeling languages and define comprehensibility appropriateness as a major requirement demanding that concepts and notation of a modeling language should be *comprehensible*. This can be measured, among others, by looking at how easy the concepts of modeling languages can be distinguished and by looking at the number of different concepts that are offered. This requirement is also backed by the following scientific publications: [LS07], [SW08a], [Pha98], [PS00], [GPD96], [BtH98].
The requirements sources indicate special importance of this requirement at the business centric layers and therefore the BM and BPM layer are rated with *csdr*-value 2.

Group: Figure out what's going on

Req. (52;69): Simulation

Simulation is a core analysis tool for process models that simulates the effect of possible input data/real world events according to an abstract representation of the real B2Bi processes. The result of such simulations can then be evaluated using performance metrics or domain expert interviews. Assuming the simulation model is a valid representation of the implemented processes, simulation aids in validating B2Bi systems. [GPD96] provide a detailed analysis of the application of simulation to process models. Also, this requirement is backed by [vdAtHW03], [Pha98] and [Kru96].
Simulation may be applied to business problems as well as technical issues so that the RS layer is the only one to get a low *csdr*-value.

Req. (53;75): Measurements
Defining performance metrics and monitoring their values is an indispensable task of any B2Bi project. Misunderstandings in communication among unequal personnel, design flaws as well as implementation errors and platform bugs lead to unintended behavior in almost all B2Bi projects. Measurements help in detecting deviations from the defined goals of B2Bi systems which may also be due to changes in the environment. This requirement can be derived from [GPD96], [Pha98] and [PS00].
Metrics are typically defined at the BM and BPM layer whereas the monitoring is typically performed at the PRIV and RS layer so that these layers receive the highest *csdr*-values.

Req. (54;76): Stochastic modeling
Stochastic modeling extends process modeling by adding probabilities to execution paths. This information can then be used, for example, to calculate the overall cost of system operation, to identify particularly important system components or to size the throughput of system components. A problem of this approach is the estimation of probability values. Consequently, the comparison of estimated and actual frequency of events is strongly recommended. This requirement can be derived from [GPD96], but also from more recent research work like [BWWR09].
The *csdr*-valuation of this requirement resembles requirement 53's valuation because it affects similar abstraction layers.

Challenge: Feasibility

Group: Adapt to real world as is

Req. (55;13): Support for business document attachments
B2Bi not only concerns the exchange of text-based data like purchase order and invoices, but also binary data like construction plans or proprietary formats. Consistently, concepts for representing document attachments is envisaged in several B2Bi standards: [OAS06], [OAS02], [OAS07], [UMM06] and [Ros02]. The requirement is also backed by integration architecture [Bec96].
At an abstract layer, document attachments may be treated analogously to text-based data, but implementations clearly need special functionality for dealing with attachments. Consequently, the CHOR, PUB, PRIV and RS layers deserve the highest *csdr*-values.

Req. (56;18): Flexible configuration of document exchange characteristics
This requirement pays tribute to the fact that the exchange of different business documents needs different QoS configurations (see requirement 38), i.e., some messages deserve a higher degree of reliability or security than others. This requirement is also related to requirement 25 (Flexible configuration of transfer/transport protocol). The difference is

that some QoS attributes may be realized at the application level, i.e., by applying transformations to the document itself, or at the transport level, i.e., applying features to the transport channel that transmits the message. The B2Bi standards [OAS02], [OAS07], [UMM06] and [Ros02] offer concepts for defining such exchange characteristics.
This requirement should be tackled at the B2Bi schema layers that focus on the specification of the exchange of messages, i.e., the CHOR and PUB layer.

Req. (57;41): External communication

External communication becomes necessary when explicit state synchronization via business transactions and business documents is not possible or inconvenient. This refers to situations where the default communication technology is not available or fails and integration partners synchronize their state via email or telephone as well as to situations where real-world events are used to signal state changes, e.g., the bank transfer of money may indicate acceptance of an invoice. This requirement is explicitly postulated in [Nor07].
Dealing with state changes using concepts different from the concepts offered by process models/implementation platforms concerns nearly all B2Bi schema layers, but it deserves special attention at the PRIV layer as the main layer for propagating state changes between backend systems and integration partners and vice versa.

Req. (58;64): Flexibility by underspecification

This requirement demands to provide the means for putting process models into production that do not describe the control flow in full detail or that even allow for processing new types of business messages. This is needed for scenarios that need extensive human involvement or that are too variable to justify fully specifying each detail in a process model. In [vdAtHW03], this kind of process execution is denoted *case handling*. In [LS07], [SMR+08] and [LS04], the need for flexibility by underspecification can be discovered as well. Note that in [SMR+08], presenting a process flexibility survey, characteristics of this requirement are also subsumed as *flexibility by deviation*. Although not originating from the B2Bi domain, advanced facilities for performing underspecified process models are presented in [DR09].
This requirement affects nearly all B2Bi schema layers, from the BPM layer that is needed as access layer for business analysts to the RS layer that needs to be prepared to accept changes to the process definition.

Req. (59;65): Adaptability

In [LS07] the need for adaptability is postulated and defined as the *"[...]ability of the workflow processes to react to exceptional circumstances, which may or may not be foreseen [...]."* This requirement is closely related to requirement 58. While flexibility by underspecification implies the ability to react to exceptional circumstances by means of incomplete process definitions, adaptability demands this ability for fully specified process models as well. The need for adaptability can also be derived from [SMR+08].
As the relationship to requirement 58 is tight, this requirement has equal *csdr*-values.

Req. (60;71): Process flexibility by design

Process flexibility by design amounts to describing all possible flows of a process model explicitly using typical definition elements provided by the modeling language like AND/OR forks, AND/OR joins and derived constructs. In an ideal world, such a process model also concludes the logic for dealing with execution exceptions. This requirement is explicitly defined in [SMR+08].

A key difference in the *csdr*-valuation of this requirement is the 0 value for the RS layer because executing a process model with lots of different paths is typically easier than allowing for modifications of an active instance.

Req. (61;72): Process flexibility by change

This requirement, identified in [SMR+08], allows for modifying process models at design time which is natural functionality of any process modeling language. [SMR+08] further identifies the need for propagating such modifications to running or terminated process instances. In so far, this requirement is also related to requirement 33 (Support for process version control). The need for changing process models is also derivable from [GPD96].
Basically, this requirement describes necessary functionality of the BM, BPM, CHOR and PUB layer. The PRIV layer deserves special attention because changes in the process models have to be checked for compatibility with backend systems. Also, functionality for propagating changes to active process instances is not standard functionality of many execution platforms.

Group: Offer wanted/needed functionality

Req. (62;73): Industry acceptance

This requirement is a consequence of the fact that business should drive IT and not the other way round. For the B2Bi context, this means that formats, protocols and technologies should be aligned with the needs of the integration partners and not that the integration partners should adapt their needs to the available technology. RosettaNet, a major B2Bi community, pays tribute to this requirement by demanding new standards to be implemented by member companies before they are finally accepted. Also, this requirement is explicitly stipulated in [SW08a].
This requirement is more important for the abstract B2Bi schema layers where domain specific concepts are needed most urgently.

Req. (63;57): Language domain appropriateness

Language domain appropriateness describes the absence of construct deficits and construct excesses of a language with respect to the domain to be modeled (cf. [NK05]). This means that anything that is in the domain should be expressible (no construct deficit) and that nothing that is not in the domain should be expressible (no construct excess). One step in assessing the domain appropriateness of B2Bi modeling languages is checking for typical concepts of B2Bi process descriptions (cf. requirements 9-14, 21-24 and 49). This requirement can also be discovered in [LS07], [SW08a] and [BtH98].
This requirement deserves special attention at the B2Bi schema layers that apply domain specific concepts.

Req. (64;62): Reasonable tool support

Reasonable tool support is a cross-cutting concern throughout all phases of any project. It is worth listing in this B2Bi requirements catalog because the participation of unequal personnel, the distributed computing setting and the management of complex associations require special support. This requirement is backed by [NK05], [SW08a], [Lam05] and [GPD96].
Due to this requirement's ubiquity, every B2Bi schema layer has high *csdr*-values with an emphasis on the layers that are affected most by the mentioned challenges.

Group: Realize business alignment

Req. (65;31): Validation

Validation targets at ensuring the correctness of artifacts. The techniques applied for performing validation vary with the artifact under consideration. While schema checks are appropriate for business documents, communication protocols may require the application of state space exploration techniques like model checking [CGP99], and the validity check of business models and business process models also requires review by domain experts. Clearly, there's no assurance that a validated artifact will 'behave as intended' when executed as any validation technique is limited. Even if verification using formal methods is applied, the problem of checking the equivalence between artifact and formal model remains. The ebXML registry standards [OAS05a, OAS05b] propose to use a central registry and repository for validating artifacts, but this requirement can also be derived from [Ros02], [vdAtHW03] and [BtH98].

The B2Bi domain requires the definition of models at several abstraction layers so that the model-centric B2Bi schema layers are rated with the highest *csdr*-values.

Req. (66;32): Life-cycle management of B2Bi artifacts; Methodology

This requirement is a call for professional management of projects according to an integrated methodology. This not only implicates the application of suitable techniques for every life-cycle phase of an artifact from requirements definition to retirement, it also demands balancing the application of different techniques to the same artifact in different life-cycle phases. For example, the application of model-driven concepts in the implementation phase also requires a sensible concept for propagating changes in the maintenance phase. [OAS05a, OAS05b] is the only B2Bi standard this requirement is detected in, but it is frequently formulated in scientific literature ([vdAtHW03], [SMR+08], [SW08a], [LS04], [DW06], [Pha98]).

The abstraction layers that deal with artifacts are valuated with the highest *csdr*-values for this requirement.

Req. (67;34): Process governance

Process governance is a method for enforcing organizational policies and standards. In the B2Bi domain, this is exceptionally hard because the participating parties typically take decisions individually. The use of a central registry/repository for implementing process governance is supposed in [OAS05a, OAS05b], but the decision who of the integration partners runs the registry/repository may be problematic. This requirement is related with requirement 65 because validation is a major task of process governance. Scientific literature also backs the need for enforcing organizational policies and standards ([LGRMD08], [DW06]).

In the B2Bi domain, process governance deserves special attention to the abstraction layers that have to be agreed upon by the integration partners. Quality assurance methodologies sometimes also require partner transparent enforcement of policies upon private processes. Consequently, the value for the PRIV layer is also set to 2.

Req. (68;61): Language organizational appropriateness

This requirement is explicitly stipulated in [NK05] and *"[...]relates the language to standards and other organizational needs within the organizational context of modeling."* This means, for example, checking whether tool support for a language is already available or can easily be acquired.

This requirement should especially be considered at abstraction layers that deal with process models.

Group: Use automation

Req. (69;38): Machine-processable format

This requirement demands more than providing a machine-processable format for business documents which is the basis for electronic interchange of information that has been available for years. It also targets at the more abstract descriptions of a B2Bi like business models and business process models. This is special because for these layers a machine-processable format also must be accessible for business personnel. Note that, although XML is claimed to be human-readable, XML based representations frequently are not sufficiently accessible (cf. requirement 48 *Visual representation*). This requirement is backed by the following B2Bi standards: [OAS06], [OAS02], [OAS07], [OAS05a, OAS05b] and also by UMM [UMM06] that remarks the possibility of mapping UMM to machine-readable languages. Also, scientific literature indicates the need for this requirement ([LGRMD08], [NK05],[Pha98]).

While machine processable formats are useful for the BM and BPM layer they are indispensable for the CHOR, PUB, PRIV and RS layer.

Req. (70;45): Auto-generation of artifacts

Auto-generation of artifacts speeds up development and avoids human processing errors. In the B2Bi domain, the generation of orchestration models from choreography models is a special application domain as this approach may be used to help in creating a distributed implementation (separate orchestrations per partner) of a commonly agreed upon choreography model (cf. [SW08b]). Assuming that such an auto-generation procedure works correctly, this approach is suited to realize conformance. This requirement is also backed by other scientific publications ([SW08a], [DW06], [Pha98]) and can be derived from B2Bi standards ([OAS06], [OAS02], [UMM06], [Nor07]).

Paying tribute to the conformance requirements of B2Bi, the *csdr*-values of the PUB and PRIV layer are set to 2.

Req. (71;51): Analysis features

Analysis features are needed for checking properties of artifacts and runtime systems. This is more general than requirement 65 in also including the state of runtime systems. Analysis features may be used for exploring artifacts/systems individually, e.g., petri nets may be used to analyze business process models and monitoring solutions may be used for measuring the throughput of messaging systems, as well as for exploring the relationship between artifacts, e.g., process logs may be checked to be consistent with process definitions using process mining techniques. None of the investigated B2Bi standards backs this requirement, but numerous scientific publications do: [LGRMD08], [NK05], [SW08b], [vdAtHW03], [Pha98], [PS00], [GPD96].

Analysis features are crucial for the success so that all abstraction layers receive *csdr*-value 2 except for the BM layer where the frequent lack of machine-processable formats limits the applicability of analysis features.

Req. (72;60): Language technical actor appropriateness

This requirement stipulated in [NK05] is related to requirement 69 in also demanding a machine-processable syntax for artifacts. Considering process models, technical actor appropriateness further demands a formal (at least operational) semantics which is the basis

for automatic analysis and execution. Automated execution and enactment is also required by [Pha98].
Putting special focus on process models compared to requirement 69, the *csdr*-valuation is the same except for the RS layer.

Req. (73;63): Traceability between process model and process execution
Assessing the correctness of process executions requires comparing the result of process runs with process definitions. This includes, for example, matching the exchange of a message with a process description that defines the exchange which may be challenging when a message type is exchanged in several types or versions of a process definition or on different paths of a process definition. Therefore, this requirement demands including sufficient information in runtime output so that matching with process descriptions is possible. [NK05], [SW08b], [vdAtHW03], [SW08a] and [BtH98] can be used to derive this requirement.
The *csdr*-values are high for all process model related abstraction layers with the highest values for the PRIV and RS layer where the definition and collection of process identification information is performed.

Challenge: Changeability

Group: Use abstraction

Req. (74;15): Technology independence of process model
Not tying a process model to a particular implementation technology provides flexibility during designing the implementation and enables reuse of process definitions. Typical business process and choreography languages comply with this principle where choreographies cannot be as independent as business process models because choreography models are used to refine business process models technically. Nonetheless, the specification of communication characteristics in choreographies is done in an abstract way, e.g., security features like confidentiality or integrity are demanded for a particular message exchange and not that TLS or XML-Encryption/Signature shall be used for that. This requirement can be derived from B2Bi standards ([OAS06], [UMM06], [Nor07], [Ros02]), scientific literature ([SW08a], [YWL04]) as well as integration architectures ([Bec96], [Kru96], [Sim05]). Considering this requirement does not make sense for the BM layer because no process models are defined there. Also, it is strongly recommended not to try to make the RS layer in whatever sense technology independent. Finally, the process models at the PUB and PRIV layer typically fix the communication technology as not doing so would require introducing and maintaining another abstraction layer.

Group: Manage associations

Req. (75;33): Management of relationships among service/process providers and service/process users
[DW06] describe the need for managing the relationships between service providers and service users for service oriented architectures. This is particularly necessary when service changes have to be performed or when the use/cost of a service has to be assessed. This also applies to the B2Bi domain. To some extent, this requirement is also backed by the ebXML registry standards ([OAS05a, OAS05b]) by defining a mechanism for event notifications.
This requirement is particularly important for the B2Bi schema layers with runtime de-

pendencies.

Group: Allow for evolution

Req. (76;35): Extensibility

The context of applications and systems changes over time and may raise new requirements that have not been foreseen. Extensibility allows for the introduction of new concepts and technologies to adapt to the new context and concerns information models, process definitions and platforms. This requirement is explicitly defined in [OAS05a, OAS05b], but can also be derived from [UMM06], [SMR+08], [LS04] and [Sim05].

This requirement is important at any abstraction layer, but particularly hard at the PUB, PRIV and RS layer.

Req. (77;66): Dynamism

This requirement postulated in [LS07] demands the possibility to perform ad-hoc changes to process definitions. This is slightly different from requirements 59 (adaptability) and 58 (flexibility by underspecification) by focusing on the change of models instead of the reaction to exceptional situations or underspecified models. The relationship with these requirements also becomes obvious by finding out that *flexibility by deviation* as defined in [SMR+08] also backs dynamism and that [DR09] provide means for implementing dynamism (cf. requirement 58).

Ad-hoc changes are most challenging for the implementation centric layers so that the PRIV and RS layers get the highest *csdr*-gradings.

Challenge: Not-Uniquely-Associated

Group: Use formal methods

Req. (78;50): Formal methods

Formal methods are a major area in computer science and frequently offer indispensable analysis features due to their outstanding rigor compared to other approaches. Though criticized for being limited in applicability from time to time, formal methods have successfully been applied in a wide range of applications, from the verification of security protocols to mathematical business models. That is why this is the only requirement the authors broke constraint C2 for and did not give a *ctrb*-value of 2 to any B2Bi challenge. This requirement can be found in several scientific publications: [LGRMD08], [NK05], [SW08b], [vdAtHW03], [Pha98], [GPD96] and [BtH98].

In the B2Bi domain, the use of formal methods should particularly be considered for the BPM, CHOR, PUB and PRIV B2Bi schema layers.

Index	Requirement	[OAS06]	[OAS02]	[OAS07]	[OAS05a, OAS05b]	[UMM06]	[Nor07]	[Ros02]	[LGRMD08]	[ATSK04]	[NK05]	[NK04]	[LS07]	[OMB07]	[WvdAD+06]	[SW08b]	[vdAtHW03]	[SMR+08]	[SW08a]	[LS04]	[Lam05]	[YWL04]	[DW06]	[Pha98]
1	Multi-level and multi-view description					+		+								+	+		+	+				+
2	Support for business transactions	+	+	0		+	0	+																
3	Support for business signals	+	+	+		+		+																
4	Hierarchical decomposition; Composability	+	+			+																+		
5	Support for binary collaborations	+	+			+	+	0																
6	Support for multi-party collaborations	+	+			+																		
7	Support for business documents	+	+	+		+	+	+				+							+					
8	Quality of service	+	+	+	+	+	+	+		+				+						+		+	+	
9	Control flow definition	+	+			+	+	0				+			+							+		
10	Exception/Error handling	+	+	+		+	+	+												+		+		
11	Role modeling	+	+	+		+	+	+														+		+
12	Role mapping	+	+	+		+																		
13	Support for business document attachments	+	+	+		+		+																
14	Support for process version control	+	0		+	+													+				+	
15	Technology independence of process model	+				+	+	+											+			+		
16	Integration partner binding		+	+																				
17	Flexible configuration of transfer/transport protocol		+	+				+				+												
18	Flexible configuration of document exchange characteristics		+	+		+		+																
19	Negotiation of business capabilities		+					+		+										+				
20	Negotiation of communication capabilities		+					+		+												+		
21	Configuration data for runtime systems		+	+				+																
22	Interfacing with backend systems			0															+		+			
23	Message correlation			+				+				+										+		
24	Communication interface			-																				

Table 2: Sources of Requirements (part 1)

Index	Requirement	[OAS06]	[OAS02]	[OAS07]	[OAS05a, OAS05b]	[UMM06]	[Nor07]	[Ros02]	[LGRMD08]	[ATSK04]	[NK05]	[NK04]	[LS07]	[OMB07]	[WvdAD$^+$06]	[SW08b]	[vdAtHW03]	[SMR$^+$08]	[SW08a]	[LS04]	[Lam05]	[YWL04]	[DW06]	[Pha98]
25	Registry functionality				+	0				+													+	
26	Repository functionality				+					+									+				+	
27	Metadata definition				+	+		+		+													+	
28	Classification of processes				+	+		+																
29	Definition of associations between processes				+		+																	
30	Cataloging of processes				+			0																
31	Validation				+			+									+							
32	Lifecycle management of B2Bi artifacts; Methodology				+	-											+	+	+	+			+	+
33	Management of relationships among service/process providers and service/process users				0																		+	
34	Process governance				+				+														+	
35	Extensibility				+	+												+		+				
36	Event propagation				+																	+	+	
37	Visual representation	0				+	+	+																+
38	Machine-processable format	+	+	+	+	0			+		+													+
39	State-based modeling					+					+											+		
40	Data formats and data codes						+	+												+	+			
41	External communication						+																	
42	Consistency	+	+	+	+	+	+	+	+							+								
43	Ease of maintenance				+		+																	
44	Ease of explanation						+																	+
45	Auto-generation of artifacts	0	+			0	+									+			+				+	+
46	Description of usage scenarios					+	+	+																
47	Description of business requirements						+	+																
48	Description of business benefits						+																	
49	Pre/Post-conditions of process/task executions	+				+	+	+	+															
50	Formal methods								+		+					+	+							+
51	Analysis features								+		+					+	+							+
52	Intelligible feedback of analysis								+															
53	Language for semantic constraint specification	0				0	0		+														+	

Table 2: Sources of Requirements (part 1)

Index	Requirement	[OAS06]	[OAS02]	[OAS07]	[OAS05a, OAS05b]	[UMM06]	[Nor07]	[Ros02]	[LGRMD08]	[ATSK04]	[NK05]	[NK04]	[LS07]	[OMB07]	[WvdAD^{+}06]	[SW08b]	[vdAtHW03]	[SMR^{+}08]	[SW08a]	[LS04]	[Lam05]	[YWL04]	[DW06]	[Pha98]
54	Semantic constraint management								+							+								
55	Semantic constraint violation traceability								+															
56	Reputation information management									+														
57	Language domain appropriateness										+		+						+					
58	Language participant language knowledge appropriateness										+								+					+
59	Language comprehensibility appropriateness										+		+						+					+
60	Language technical actor appropriateness										+													+
61	Language organizational appropriateness										+													
62	Reasonable tool support										+								+		+			
63	Traceability between process model and process execution										+					+	+		+					
64	Flexibility by underspecification												+				+	+		+				
65	Adaptability												+					+						
66	Dynamism												+					+						
67	Control flow patterns														+									
68	Data oriented process definition	+				+	0	+							+									
69	Simulation																+							+
70	Usage of standards	+	+	+	+	+	+	+								+	+		+					
71	Process flexibility by design																	+						
72	Process flexibility by change																	+						
73	Industry acceptance							+											+					
74	Semantic description to support dynamic service discovery and invocation																					+		
75	Measurements																							+
76	Stochastic modeling																							
77	Documentation				+	+	+	+																
78	Asynchronous and synchronous interaction	+	+	+	+	+		+														+		

Table 2: Sources of Requirements (part 1)

Index	Requirement	[PS00]	[GPD96]	[BtH98]	[Bec96]	[Kru96]	[Sim05]
1	Multi-level and multi-view description	+		+	+	+	+
2	Support for business transactions						
3	Support for business signals						
4	Hierarchical decomposition; Composability		+	+	+	+	+
5	Support for binary collaborations				+		+
6	Support for multi-party collaborations						
7	Support for business documents			+	+	+	+
8	Quality of service			+			+
9	Control flow definition			+	+	+	+
10	Exception/Error handling			+		+	+
11	Role modeling	+			+		
12	Role mapping						
13	Support for business document attachments				+		
14	Support for process version control						
15	Technology independence of process model				+	+	+
16	Integration partner binding						
17	Flexible configuration of transfer/transport protocol						+
18	Flexible configuration of document exchange characteristics						
19	Negotiation of business capabilities						
20	Negotiation of communication capabilities						
21	Configuration data for runtime systems						
22	Interfacing with backend systems						+
23	Message correlation						
24	Communication interface						
25	Registry functionality						
26	Repository functionality						+
27	Metadata definition					+	
28	Classification of processes						

Table 3: Sources of Requirements (part 2)

Index	Requirement	[PS00]	[GPD96]	[BtH98]	[Bec96]	[Kru96]	[Sim05]
29	Definition of associations between processes						
30	Cataloging of processes						
31	Validation			+			
32	Lifecycle management of B2Bi artifacts; Methodology						
33	Management of relationships among service/process providers and service/process users						
34	Process governance						
35	Extensibility						+
36	Event propagation						
37	Visual representation				+	+	+
38	Machine-processable format						
39	State-based modeling						
40	Data formats and data codes						
41	External communication						
42	Consistency						
43	Ease of maintenance						
44	Ease of explanation						
45	Auto-generation of artifacts						
46	Description of usage scenarios		+		+		
47	Description of business requirements						
48	Description of business benefits						
49	Pre/Post-conditions of process/task executions			+			
50	Formal methods		+	+			
51	Analysis features	+	+				
52	Intelligible feedback of analysis		+				
53	Language for semantic constraint specification						
54	Semantic constraint management						
55	Semantic constraint violation traceability						
56	Reputation information management						
57	Language domain appropriateness			+			

Table 3: Sources of Requirements (part 2)

Index	Requirement	[PS00]	[GPD96]	[BtH98]	[Bec96]	[Kru96]	[Sim05]
58	Language participant language knowledge appropriateness	+	+				
59	Language comprehensibility appropriateness	+	+	+			
60	Language technical actor appropriateness						
61	Language organizational appropriateness						
62	Reasonable tool support		+				
63	Traceability between process model and process execution			+			
64	Flexibility by underspecification						
65	Adaptability						
66	Dynamism						
67	Control flow patterns						
68	Data oriented process definition						
69	Simulation		+			+	
70	Usage of standards						
71	Process flexibility by design						
72	Process flexibility by change		+				
73	Industry acceptance						
74	Semantic description to support dynamic service discovery and invocation						
75	Measurements	+	+				
76	Stochastic modeling		+				
77	Documentation		+				
78	Asynchronous and synchronous interaction			+			

Table 3: Sources of Requirements (part 2)

Index (ordered)	Index (survey)	Requirement	Requirement Group	Communication among unequal personnel	Agreement	Management of complex associations	Homogenization of computing resources	Comprehensibility	Feasibility	Changeability
1	58	Language participant language knowledge appropriateness	Use specific media that help	2	0	0	0	1	0	0
2	52	Intelligible feedback of analysis	Use specific media that help	2	0	0	0	1	0	0
3	77	Documentation	Describe context of application	2	1	0	0	1	1	1
4	46	Description of usage scenarios	Describe context of application	2	0	0	0	1	0	0
5	47	Description of business requirements	Describe context of application	2	1	0	0	1	1	0
6	48	Description of business benefits	Describe context of application	2	0	0	0	1	1	0
7	28	Classification of processes	Group processes together	2	0	0	0	1	0	0
8	29	Definition of associations between processes	Group processes together	2	0	0	0	1	0	0
9	2	Support for business transactions	Define synchronization constructs	0	2	0	1	0	0	0
10	3	Support for business signals	Define synchronization constructs	0	2	0	1	0	0	0
11	5	Support for binary collaborations	Define synchronization constructs	0	2	0	0	1	0	0
12	7	Support for business documents	Define synchronization constructs	0	2	0	0	0	0	0
13	9	Control flow definition	Define synchronization constructs	0	2	0	1	0	2	1
14	53	Language for semantic constraint specification	Describe state space of collaboration	1	2	0	0	1	1	1
15	68	Data oriented process definition	Describe state space of collaboration	1	2	0	0	0	0	0
16	49	Pre/Post-conditions of process/task executions	Describe state space of collaboration	1	2	0	0	0	1	0
17	16	Integration partner binding	Allow for partner specifics	0	2	0	0	0	0	0
18	19	Negotiation of business capabilities	Allow for partner specifics	0	2	1	0	0	0	0
19	20	Negotiation of communication capabilities	Allow for partner specifics	0	2	1	1	0	0	0
20	56	Reputation information management	Allow for unknown partners	0	0	2	0	0	0	0
21	6	Support for multi-party collaborations	Define constructs for complex interactions	0	1	2	0	0	0	0
22	11	Role modeling	Define constructs for complex interactions	1	0	2	0	1	0	1
23	12	Role mapping	Define constructs for complex interactions	0	0	2	0	0	0	1
24	67	Control flow patterns	Define constructs for complex interactions	1	1	2	1	1	1	0
25	17	Flexible configuration of transfer/transport protocol	Overcome technical communication obstacles	0	0	2	1	0	0	1
26	27	Metadata definition	Manage associations	0	0	2	1	0	0	1
27	30	Cataloging of processes	Manage associations	0	0	2	0	0	0	1
28	36	Event propagation	Manage associations	0	0	2	0	0	0	0
29	74	Semantic description to support dynamic service discovery and invocation	Manage associations	0	1	2	0	0	0	1
30	25	Registry functionality	Manage associations	0	0	2	0	0	0	1
31	26	Repository functionality	Manage associations	0	0	2	0	0	0	1

Table 4: Requirements-Challenge Relation

Index (ordered)	Index (survey)	Requirement	Requirement Group	Communication among unequal personnel	Agreement	Management of complex associations	Homogenization of computing resources	Comprehensibility	Feasibility	Changeability
32	54	Semantic constraint management	Use association management facilitators	0	1	2	1	0	1	1
33	14	Support for process version control	Use association management facilitators	0	1	2	0	0	0	1
34	70	Usage of standards	Use association management facilitators	1	1	2	1	0	1	0
35	40	Data formats and data codes	Use association management facilitators	1	1	2	1	0	0	0
36	43	Ease of maintenance	Use association management facilitators	0	0	2	1	0	1	1
37	78	Asynchronous and synchronous interaction	Deal with basic distributed interaction styles	0	0	1	2	0	1	0
38	8	Quality of service	Deal with distributed communication	0	1	0	2	0	0	0
39	10	Exception/Error handling	Deal with distributed communication	0	1	0	2	0	0	0
40	23	Message correlation	Deal with distributed communication	0	0	1	2	0	0	0
41	24	Communication interface	Deal with distributed communication	0	0	0	2	0	1	0
42	42	Consistency	Manage state space	0	1	0	2	0	1	0
43	55	Semantic constraint violation traceability	Manage state space	0	0	1	2	0	0	0
44	21	Configuration data for runtime systems	Deal with heterogeneity	0	1	0	2	0	0	1
45	22	Interfacing with backend systems	Deal with heterogeneity	0	0	1	2	0	1	1
46	1	Multi-level and multi-view description	Decompose problem	1	0	0	0	2	0	0
47	4	Hierarchical decomposition; Composability	Decompose problem	1	0	0	1	2	0	0
48	37	Visual representation	Use adequate representations	1	0	0	0	2	0	0
49	39	State-based modeling	Use adequate representations	1	1	0	1	2	0	0
50	44	Ease of explanation	Use adequate representations	1	0	0	0	2	0	0
51	59	Language comprehensibility appropriateness	Use adequate representations	0	0	0	0	2	0	0
52	69	Simulation	Figure out what's going on	0	0	1	0	2	1	1
53	75	Measurements	Figure out what's going on	1	1	0	1	2	0	0
54	76	Stochastic modeling	Figure out what's going on	1	0	1	1	2	1	0
55	13	Support for business document attachments	Adapt to real world as is	0	1	0	0	0	2	0
56	18	Flexible configuration of document exchange characteristics	Adapt to real world as is	0	0	1	0	0	2	1
57	41	External communication	Adapt to real world as is	0	1	0	0	0	2	0
58	64	Flexibility by underspecification	Adapt to real world as is	0	0	1	0	0	2	0
59	65	Adaptability	Adapt to real world as is	0	0	1	1	0	2	0
60	71	Process flexibility by design	Adapt to real world as is	0	0	1	1	0	2	0
61	72	Process flexibility by change	Adapt to real world as is	0	0	1	1	0	2	1
62	73	Industry acceptance	Offer wanted/needed functionality	1	1	1	1	0	2	0
63	57	Language domain appropriateness	Offer wanted/needed functionality	1	0	0	0	1	2	0
64	62	Reasonable tool support	Offer wanted/needed functionality	0	1	1	1	1	2	1
65	31	Validation	Realize business alignment	0	0	1	1	0	2	0

Table 4: Requirements-Challenge Relation

Index (ordered)	Index (survey)	Requirement	Requirement Group	Communication among unequal personnel	Agreement	Management of complex associations	Homogenization of computing resources	Comprehensibility	Feasibility	Changeability
66	32	Lifecycle management of B2Bi artifacts; Methodology	Realize business alignment	0	0	1	1	0	2	1
67	34	Process governance	Realize business alignment	0	0	1	0	0	2	1
68	61	Language organizational appropriateness	Realize business alignment	0	0	0	0	0	2	0
69	38	Machine-processable format	Use automation	0	1	1	0	0	2	1
70	45	Auto-generation of artifacts	Use automation	0	1	1	1	0	2	1
71	51	Analysis features	Use automation	0	1	1	0	1	2	1
72	60	Language technical actor appropriateness	Use automation	0	1	1	1	0	2	1
73	63	Traceability between process model and process execution	Use automation	0	1	1	1	0	2	0
74	15	Technology independence of process model	Use abstraction	1	0	1	1	1	0	2
75	33	Management of relationships among service/process providers and service/process users	Manage associations	0	0	1	0	0	0	2
76	35	Extensibility	Allow for evolution	0	0	1	1	0	1	2
77	66	Dynamism	Allow for evolution	0	0	1	0	0	1	2
78	50	Formal methods	Use formal methods	1	1	1	1	1	1	1

Table 4: Requirements-Challenge Relation

Index (ordered)	Index (survey)	Requirement	Requirement Group	Business Model	Business Process Model	Choreography Model	Public Orchestration Definition	Private Orchestration Definition	Runtime Systems	Sum
1	58	Language participant language knowledge appropriateness	Use specific media that help	1	2	1	0	0	0	4
2	52	Intelligible feedback of analysis	Use specific media that help	1	2	1	1	1	2	8
3	77	Documentation	Describe context of application	2	2	2	1	1	2	10
4	46	Description of usage scenarios	Describe context of application	2	2	1	0	1	0	6
5	47	Description of business requirements	Describe context of application	2	2	0	0	0	0	4
6	48	Description of business benefits	Describe context of application	2	1	0	-	-	0	3
7	28	Classification of processes	Group processes together	1	2	1	0	0	1	5
8	29	Definition of associations between processes	Group processes together	2	2	1	1	2	2	10
9	2	Support for business transactions	Define synchronization constructs	-	1	2	2	2	1	8
10	3	Support for business signals	Define synchronization constructs	-	0	1	2	2	1	6

Table 5: Requirements-Abstraction Layer Relation

Index (ordered)	Index (survey)	Requirement	Requirement Group	Business Model	Business Process Model	Choreography Model	Public Orchestration Definition	Private Orchestration Definition	Runtime Systems	Sum
11	5	Support for binary collaborations	Define synchronization constructs	-	2	2	2	1	0	7
12	7	Support for business documents	Define synchronization constructs	0	2	2	2	2	2	10
13	9	Control flow definition	Define synchronization constructs	-	2	1	2	2	0	7
14	53	Language for semantic constraint specification	Describe state space of collaboration	1	2	2	1	1	1	8
15	68	Data oriented process definition	Describe state space of collaboration	0	2	2	1	2	0	7
16	49	Pre/Post-conditions of process/task executions	Describe state space of collaboration	1	2	2	0	0	1	6
17	16	Integration partner binding	Allow for partner specifics	-	0	1	1	2	2	6
18	19	Negotiation of business capabilities	Allow for partner specifics	2	2	1	1	0	-	6
19	20	Negotiation of communication capabilities	Allow for partner specifics	0	1	2	2	0	0	5
20	56	Reputation information management	Allow for unknown partners	1	1	1	1	1	1	6
21	6	Support for multi-party collaborations	Define constructs for complex interactions	0	2	2	2	1	0	7
22	11	Role modeling	Define constructs for complex interactions	1	2	2	1	0	0	6
23	12	Role mapping	Define constructs for complex interactions	0	2	2	2	1	0	7
24	67	Control flow patterns	Define constructs for complex interactions	-	2	1	2	2	0	7
25	17	Flexible configuration of transfer/transport protocol	Overcome technical communication obstacles	-	-	1	2	0	1	4
26	27	Metadata definition	Manage associations	0	1	2	2	1	0	6
27	30	Cataloging of processes	Manage associations	-	1	1	1	1	2	6
28	36	Event propagation	Manage associations	-	1	1	1	1	2	6
29	74	Semantic description to support dynamic service discovery and invocation	Manage associations	-	1	2	2	1	2	8
30	25	Registry functionality	Manage associations	0	1	2	2	1	1	7
31	26	Repository functionality	Manage associations	-	0	1	1	1	2	5
32	54	Semantic constraint management	Use association management facilitators	0	1	2	2	1	1	7
33	14	Support for process version control	Use association management facilitators	0	2	2	2	2	1	9
34	70	Usage of standards	Use association management facilitators	1	1	2	2	1	1	8
35	40	Data formats and data codes	Use association management facilitators	-	0	1	2	2	1	6
36	43	Ease of maintenance	Use association management facilitators	-	0	0	1	2	1	4
37	78	Asynchronous and synchronous interaction	Deal with basic distributed interaction styles	-	1	1	2	2	1	7
38	8	Quality of service	Deal with distributed communication	0	0	1	2	2	2	7
39	10	Exception/Error handling	Deal with distributed communication	-	1	1	1	2	2	7
40	23	Message correlation	Deal with distributed communication	-	0	1	2	1	1	5
41	24	Communication interface	Deal with distributed communication	-	0	0	1	1	2	4

Table 5: Requirements-Abstraction Layer Relation

Index (ordered)	Index (survey)	Requirement	Requirement Group	Business Model	Business Process Model	Choreography Model	Public Orchestration Definition	Private Orchestration Definition	Runtime Systems	Sum
42	42	Consistency	Manage state space	1	2	1	2	2	1	9
43	55	Semantic constraint violation traceability	Manage state space	0	1	1	1	1	2	6
44	21	Configuration data for runtime systems	Deal with heterogeneity	-	-	0	1	1	2	4
45	22	Interfacing with backend systems	Deal with heterogeneity	-	0	0	0	2	1	3
46	1	Multi-level and multi-view description	Decompose problem	1	2	1	1	1	0	6
47	4	Hierarchical decomposition; Composability	Decompose problem	0	2	2	2	2	0	8
48	37	Visual representation	Use adequate representations	1	2	1	1	1	0	6
49	39	State-based modeling	Use adequate representations	1	2	1	1	1	0	6
50	44	Ease of explanation	Use adequate representations	1	2	1	1	1	1	7
51	59	Language comprehensibility appropriateness	Use adequate representations	2	2	1	1	1	-	7
52	69	Simulation	Figure out what's going on	1	2	1	2	2	0	8
53	75	Measurements	Figure out what's going on	1	1	0	0	1	2	5
54	76	Stochastic modeling	Figure out what's going on	1	2	0	0	1	1	5
55	13	Support for business document attachments	Adapt to real world as is	-	0	1	2	1	1	5
56	18	Flexible configuration of document exchange characteristics	Adapt to real world as is	-	0	2	2	1	0	5
57	41	External communication	Adapt to real world as is	-	1	1	1	2	1	6
58	64	Flexibility by underspecification	Adapt to real world as is	0	2	1	1	2	1	7
59	65	Adaptability	Adapt to real world as is	0	2	1	1	2	1	7
60	71	Process flexibility by design	Adapt to real world as is	1	2	1	1	2	0	7
61	72	Process flexibility by change	Adapt to real world as is	1	1	1	1	2	1	7
62	73	Industry acceptance	Offer wanted/needed functionality	1	1	1	1	0	0	4
63	57	Language domain appropriateness	Offer wanted/needed functionality	1	2	2	1	1	-	7
64	62	Reasonable tool support	Offer wanted/needed functionality	1	2	2	2	2	1	10
65	31	Validation	Realize business alignment	1	1	2	2	2	0	8
66	32	Lifecycle management of B2Bi artifacts; Methodology	Realize business alignment	0	1	2	2	1	0	6
67	34	Process governance	Realize business alignment	1	2	2	2	2	0	9
68	61	Language organizational appropriateness	Realize business alignment	1	2	2	1	1	-	7
69	38	Machine-processable format	Use automation	0	1	2	2	2	2	9
70	45	Auto-generation of artifacts	Use automation	-	0	1	2	2	1	6
71	51	Analysis features	Use automation	1	2	2	2	2	2	11
72	60	Language technical actor appropriateness	Use automation	0	1	2	2	2	1	8
73	63	Traceability between process model and process execution	Use automation	0	1	1	1	2	2	7
74	15	Technology independence of process model	Use abstraction	%	2	1	0	0	-	3
75	33	Management of relationships among service/process providers and service/process users	Manage associations	0	0	1	2	2	1	6
76	35	Extensibility	Allow for evolution	1	1	1	2	2	2	9

Table 5: Requirements-Abstraction Layer Relation

Index (ordered)	Index (survey)	Requirement	Requirement Group	Business Model	Business Process Model	Choreography Model	Public Orchestration Definition	Private Orchestration Definition	Runtime Systems	Sum
77	66	Dynamism	Allow for evolution	-	0	0	1	2	2	5
78	50	Formal methods	Use formal methods	0	2	2	2	1	0	7
			Sum:	40	100	98	104	101	66	

Table 5: Requirements-Abstraction Layer Relation

5 Discussion and Future Work

This section discusses the approach of this work in general, the need for operationalization of the requirements set for concrete uses as well as some precautions to be taken when using the requirements set.

The work presented here follows an inductive approach based on a literature review. The limitations of such an approach are alleviated by choosing an extensive set of requirements sources. While B2Bi standards capture core functionality to be provided for B2Bi projects, reference models define best practice knowledge of modeling and managing processes. Scientific literature complements these sources and provides access to state-of-the art B2Bi technologies as well as real-world experience covered in case/field studies and expert interviews. An indicator for the comprehensiveness of our requirements set is the decreasing rate of new requirements per requirements source. For the last three sources investigated, no new requirements have been discovered.

The sample of requirements sources for the work at hand is not completely random. Standards, reference models and literature known by the authors from former projects have been included in the sources list for the work at hand and then these have been complemented by performing a keyword search using scientific search engines. The filtering of these results is based on the scope of this work which is discussed in section 3 and visualized by the B2Bi schema presented in section 1. Clearly, this implies a B2Bi notion influenced by the authors' experience and has to be considered when applying the requirements list to different research fields with a deviating B2Bi notion. The aggregation of requirements of this work was lead by the goals of presenting both a comprehensive and manageable list (cf. section 2). Future work therefore includes performing questionnaire surveys or expert interviews for validating comprehensiveness as well as case studies in managing B2Bi projects or assessing B2Bi products for validating manageability.

Further project-specific operationalization is needed for aligning concrete projects with this work's requirements set. This concerns a project-specific valuation for the relative importance of each requirement as well as a refinement of selected requirements. For example, requirement 30 (registry functionality) may only be of minor importance for a binary B2Bi project with relatively few different types of processes and services while it may be of crucial importance for a B2Bi project that brings together the members of a B2Bi community. Accordingly, a refinement for the requirements may be needed, e.g., whether semantic research capabilities are needed for a registry or not. Future work with respect to this issue therefore concerns a field study of B2Bi projects. Ideally, criteria for discriminating different B2Bi types like *Case Handling vs. Straight Through Processing* [vdAtHW03], *Extended Enterprise Integration vs. Market B2Bi* [GVL+05] and the different types of *Cross-organizational Service Composition* [SJH08] are to be included in this field study for providing help in tailoring the requirements set to a concrete project.
Also, the interrelations of requirements may need further investigation which is not only relevant for requirements with similar goals. The degree of complementarity and contradiction of requirements is relevant for giving project managers feedback on the effect of attacking a particular requirement. Again, a field study that differentiates B2Bi types should reveal valuable and insightful results.

There are some precautions to be taken when using the requirements set. The requirement names necessarily are ambiguous to some extent which is due to the fact that many B2Bi notions are used in similar yet different contexts. A good example for that is the question whether a registry includes a repository or a repository includes a registry. Accordingly, the *ctrb*- and *csdr*-valuations of section 4.2 vary with the researcher's background and experience who is asked to perform the valuation. This also affected the derivation of the *ctrb*- and *csdr*-valuations in tables 4 and 5, although the authors all are members of the same group. For example, for only 14 out of 78 requirements the highest *ctrb*-value per requirement, which has to be unique according to constraint C1, was chosen by all three authors identically. Therefore, project participants should align their understanding of the B2Bi requirements by consulting the requirements descriptions presented in section 4.2 before applying the set of requirements to a particular project task.

Finally, the column and row sums of table 5 should not be used to deduce general comparisons between B2Bi schema layers or between requirements. The lower column sums of the BM and RS layer merely reflect the scope of this work because these layers are at the boundary of the aspects considered. A more business oriented view on B2Bi surely would result in a higher value for the BM model and/or not even distinguish between some lower level layers. The row values are biased by the generality of the requirements, i.e., general requirements like *reasonable tool support* tend to get higher sums than more specific requirements like *technology independence of process model* because they apply to more abstraction layers. So, high row values may be interpreted as hints that certain requirements are of high importance for many layers and, hence, should be explicitly considered in all phases of a B2Bi project that deal with these layers.

6 Conclusion

In this report, we have presented a comprehensive set of requirements for the analysis, design, development and maintenance of B2Bi information systems that is manageable in size. This set has been derived by selecting and evaluating B2Bi standards, reference architectures and scientific literature as requirements sources where a decreasing number of requirements per source indicates comprehensiveness of the requirements set. Each requirement is associated with sources it has been discovered in which enables traceability and defines a starting point for refining requirements if needed.

The use of the requirements set is operationalized by associating requirements with B2Bi challenges and B2Bi schema layers. The association with B2Bi challenges helps in tailoring the set of requirements to different B2Bi scenarios and also eases identifying relations between requirements. The association with B2Bi schema layers supports the decision when to consider which requirements during a B2Bi project and which technologies and research areas to investigate for satisfying certain requirements.

By providing this kind of information, this report lays the foundation for assessing and selecting tools, platforms and methodologies for B2Bi projects as well as further research on the requirements of more specialized types of B2Bi projects.

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