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Advanced automation technologies and their applications — Requirements for establishing manufacturing enterprise process interoperability —

Part 1: Framework for enterprise interoperability

Technologies d'automatisation avancées et leurs applications — Exigences relatives à l'établissement d'un processus d'interopérabilité pour les entreprises de fabrication —

Partie 1: Cadre pour l'interopérabilité d'entreprise

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11354-1 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 310, *Advanced automation technologies and their applications*, in collaboration with Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 5, *Interoperability, integration, and architectures for enterprise systems and automation applications,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement). This part of ISO 11354 is based on work carried out in European projects such as ATHENA[11] and INTEROP NoE[20].

ISO 11354 consists of the following parts, under the general title *Advanced automation technologies and their applications — Requirements for establishing manufacturing enterprise process interoperability*:

— *Part 1: Framework for enterprise interoperability*

The following parts are planned:

— *Part 2: Maturity model for assessing enterprise interoperability*

— *Part 3: Requirements for information and communication technology-enabled enterprise interoperability*

Introduction

The ability of an enterprise to interoperate with others is not only a recognized quality and advantage for gaining competitiveness in today's market, but is becoming a question of survival for many companies, especially for small or medium size enterprises (SMEs). Enterprises require more interoperations during the entire life cycle of a product to reduce cost and shorten delays. Increased interoperations enable an enterprise to propose new products for the market in a network of organizations. Many stakeholders believe that enterprise interoperability is an area in which research can lead to outstanding results in terms of innovation, leading to economic growth and employment (see Reference [16]).

Enterprise interoperability as an engineering discipline is not yet well defined; interoperability is still a vague concept that has many definitions and connotations in different sectors and domains. This leads to communication difficulties and misunderstandings. Consequently, it is essential to define the concept of interoperability as relevant to enterprise interoperation.

Enterprise systems fail to interoperate because of barriers of various categories. Interoperability barriers are therefore an important concept, and this part of ISO 11354 identifies three categories of interoperability barriers, namely: conceptual, technological and organizational. Interoperability barriers need to be categorized in standard ways and existing interoperability knowledge and solutions need to be related to these barriers in order to facilitate interoperability in design and implementation for industry.

ISO 11354 considers interoperability as a generic concept, and it is assumed that common problems of interoperability failure and solutions to overcome them can be identified and developed for any particular enterprise. Therefore, ISO 11354 considers enterprise interoperability to be an engineering discipline, separating it from other business-related issues. Interoperability is seen as a necessary support to enable business collaboration, but interoperability is not the business collaboration itself.

Advanced automation technologies and their applications — Requirements for establishing manufacturing enterprise process interoperability —

Part 1: Framework for enterprise interoperability

1 Scope

The purpose of this part of ISO 11354 is to specify a Framework for Enterprise Interoperability (FEI) that establishes dimensions and viewpoints to address interoperability barriers, their potential solutions, and the relationships between them.

ISO 11354 applies to manufacturing enterprises, but can also apply to other kinds of enterprises. It is intended for use by stakeholders who are concerned with developing and deploying solutions based on information and communication technology for manufacturing enterprise process interoperability. It focuses on, but is not restricted to, enterprise (manufacturing or service) interoperability.

This part of ISO 11354 specifies the following:

— viewpoints for addressing stakeholder concerns for the exchange of entities (information objects or physical objects) at the operational levels of enterprises at which interoperability is required;

— a framework for structuring these stakeholder concerns (business, process, service, data), the barriers relating to enterprise interoperability (conceptual, technological, organizational) and the approaches to overcome barriers (integrated, unified, federated), with contents identifying the various kinds of solutions available to enable interoperability.

This part of ISO 11354 does not specify the specific mechanisms for the exchange of entities (information objects or physical objects), nor the manner in which interoperability solutions are implemented.

Three annexes provide additional information. Annex A describes how existing interoperability frameworks can be related to the concepts of this framework. Annex B shows examples of using the FEI to identify and categorize interoperability barriers, knowledge and solutions. Annex C provides a methodological guideline on how the FEI can be used in an interoperability engineering project.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
enterprise interoperability
ability of enterprises and entities within those enterprises to communicate and interact effectively

NOTE Interoperability is considered as significant if the interactions can take place in at least one of the four areas of interoperability concerns: data, service, process and business.

2.2
interoperability barrier
incompatibility between entities within the enterprise that obstructs the exchange of information and other entities, the utilization of services or the common understanding of exchanged items

NOTE This part of ISO 11354 defines three categories of barriers: conceptual, technological and organizational.

2.3
interoperability concern
aspect of interaction or interoperation that is of interest to an enterprise stakeholder

NOTE This part of ISO 11354 defines four areas of interoperability concerns: data, service, process and business.

2.4
interoperability approach
manner in which interoperability problems are solved and barriers are overcome

NOTE This part of ISO 11354 defines three interoperability approaches: integrated, unified and federated.

3 Abbreviated terms

AIF	ATHENA Interoperability Framework[10]
ASA	Adaptive Software Architecture
ASOA	Advanced Service-Oriented Architecture
ATHENA	Advanced Technologies for Heterogeneous Enterprise Networks and their Applications[11]
BIF	Business Interoperability Framework[13]
CPD	Collaborative Product Development
EIF	European Interoperability Framework[15]
FEI	Framework for Enterprise Interoperability
FRISCO	Framework of Information System Concepts[17]
ICT	Information and Communication Technology
IS	Information System
IT	Information Technology
INTEROP	Interoperability Research for Networked Enterprises Applications and Software[20]
LISI	Levels of Information Systems Interoperability[22]
OSI	Open System Interconnection[8]
PPM	Product Portfolio Management
PSL	Process Specification Language[6]
SCM	Supply Chain Management

SME Small or Medium size Enterprise

SOA Service-Oriented Architecture

4 Conformity with this part of ISO 11354

In order to claim conformity with this part of ISO 11354, any particular interoperability product (including methods and software) shall be able to be positioned within the FEI defined in this part of ISO 11354.

NOTE 1 In this part of ISO 11354, positioning is used to mean the activity of identifying correspondence connections between entities of the same kind.

This positioning shall include the related interoperability barriers, interoperability concerns and interoperability approaches. Additionally, the positioning shall also address the appropriate supplementary dimensions identified in this part of ISO 11354 and demonstrate their conformance to the normative requirements for each relevant interoperability approach identified.

NOTE 2 Annex A describes how existing interoperability frameworks can be related to the concepts of this framework. Examples of how such positionings can be achieved and documented are found in Annex B. Annex C provides a methodological guideline on how the FEI can be used in an interoperability engineering project.

5 Viewpoints addressed by the enterprise interoperability framework

5.1 General framework requirements

The framework shall enable the representation of the viewpoints as defined in this clause to represent concerns, barriers, and approaches relative to enterprise interoperability. The framework shall comprise the structures specified in Clause 6 to represent the relationships between the viewpoints and their elements.

Interoperability viewpoints shall express the needs of the enterprise stakeholder who is concerned with the following:

a) identifying and resolving interoperability issues, and

b) the structured representation of those needs and their fulfilments.

The latter can be achieved by the interoperability framework presented in this part of ISO 11354.

Stakeholder needs for enterprise interoperability refer to the ability of enterprises (or part of them) to interact through the exchange of information and other entities, such as material objects, energy, etc. Interoperability is a necessary support to enable business collaboration, but interoperability is not the business collaboration itself.

Enterprise interoperability can apply to both inter- and intra-enterprise needs and includes the concepts of extended enterprise, virtual enterprise and subsystems of one enterprise, be they distributed, networked or located in a single site, and whatever their production types (e.g. discrete, continuous), natures (e.g. manufacturing, service) or company size.

NOTE Enterprise interoperability is not an all or nothing situation. There are different extents and different kinds of enterprise interoperability. It is not appropriate to say “enterprise A is interoperable but enterprise B is not”. It is important to establish how much interoperability is necessary, in terms of its extent and functionality.

5.2 Interoperability concern viewpoint

5.2.1 Categories of interoperability concerns

The interoperability concern viewpoint shall describe the categories of concerns that are relevant for enterprise interoperability. Although the descriptions are primarily related to ICT-based applications, they can apply to non-computerized systems as well.

When considering enterprise interoperability, the following four categories of interoperability concerns shall be identified, as illustrated in Figure 1:

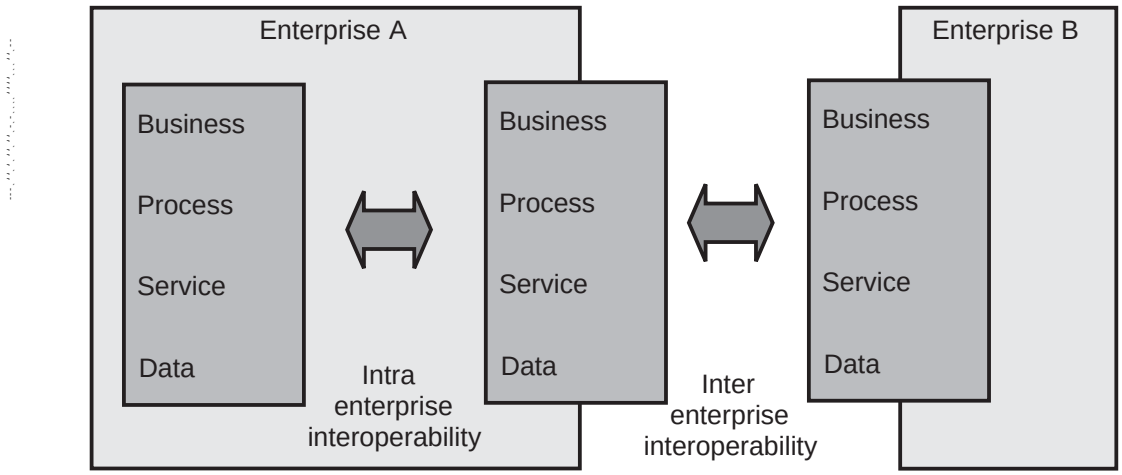
— data,

— service,

— process, and

— business.

Data are used by services. Services are employed by processes to realize the business of the enterprise. From another perspective, the goal of an enterprise is to run its business. The business is realized through processes. Processes employ services that in turn need data to perform activities.



NOTE Source: ATHENA[11].

Figure 1 — Interoperability concerns

NOTE Interoperability of communication is an essential condition to enable interoperability. However, for ICT systems, interoperability of communication is provided by communication protocols (e.g. from cable connection to the protocol of layers 1 to 4 of the OSI model in ISO/IEC 7498-1), and interfaces (layers 5 to 7 of the OSI model). Therefore, interoperability of communications is not subject of further description in this part of ISO 11354.

5.2.2 Data interoperability concern

Data interoperability refers to the ability of all kinds of entities to exchange data items. Therefore, concerns on the incompatibilities between partner data systems shall be described prior to any active collaboration. Data interoperability is crucial for most forms of enterprise interoperability because it is one of the following:

a) the substance of the exchange, or

b) a factual record of the exchange of entities, or

c) a necessary capability for exchange negotiation.

The concern extends to both non-electronic data (e.g. physical documents, human conversations) and electronic data (e.g. data files, data stored in a database).

Data interoperation occurs when either

— a particular entity is capable of receiving and using needed data items provided by an external source, or conversely,

— an external source is capable of receiving and using needed data items from an entity within the enterprise.

EXAMPLE Two enterprises exhibit data interoperation when they engage in exchanging data files such as spreadsheet files, or in a more or less continuous manner in the case of process interoperability or service interoperability.

Data incompatibilities can arise between cooperating or collaborating business entities having different data systems using different data schemas with different syntax and semantics, different data models (e.g. informal, hierarchical, relational, etc.), different modes of control or different assignments of responsibilities and authorizations for data systems, operation and change management. Concerns about the incompatibilities between data systems shall be described prior to any active collaboration.

The description shall include the detailing of the differing data exchange needs of each business entity and related capabilities, and the explicit identification of all relevant responsibilities and authorizations. The description shall also document the data exchange incompatibilities that need to be resolved.

For data held in electronic form, data models and queries are structured in accordance with schemas (i.e. vocabularies and sets of data structures) that are associated with particular applications. In this case, the description of the interoperability of data shall include finding and mapping the schemas of possibly heterogeneous data structures, which can reside on different computing devices with different operating systems and different knowledge or information management systems.

NOTE Data interoperation is accomplished by resolving conceptual and any other differences between enterprise data systems (e.g. schema representation, differing responsibilities), as well as finding appropriate technology solutions.

5.2.3 Service interoperability concern

Service interoperability refers to the ability of business entities to request, provide, and utilize each other's services.

Service interoperation occurs when either

— a particular service is capable of requesting, receiving and using needed information provided by an external service, or conversely,

— an external service is capable of requesting, receiving and using needed information from a service within the enterprise.

Incompatibilities can arise for cooperating or collaborating business entities that have different service models, different modes of control and/or different assignments of responsibilities and authorization for service selection, operation and change management. Concerns about the incompatibilities between business entity services that are to be employed in any exchange of entities shall be described prior to any active collaboration, unless it is intended that the collaboration be achieved through the use of agent negotiation or similar technology.

The description shall include the detailing of the business services themselves, and the detailing of their assignment to different enterprise operational systems. It shall also include the detailing of those services that identify, compose and operate applications that have been designed and implemented independently. The description shall also document the service incompatibilities that need to be resolved.

NOTE 1 Service interoperation is accomplished by resolving conceptual and any other differences between enterprise services (e.g. service granularity, differing responsibilities), as well as finding appropriate technology.

NOTE 2 Service interoperation has three aspects:

— service use by a requestor of service from a service provider,

— service response from a service provider to a service requestor, and

— interconnecting different services to form a complex service (the last case is related to process interoperability as well).

NOTE 3 A service is performed by a resource (computer type, machine type, human type) to provide an operation.

5.2.4 Process interoperability concerns

Process interoperability refers to the ability of business entities to exchange information and other entities needed for process operation.

Process interoperation occurs when either

— a particular process is capable of receiving and using needed information and other entities provided by an external process, or conversely,

— an external process is capable of receiving and using needed information and other entities from a process within the enterprise.

Process incompatibilities can arise for cooperating or collaborating business entities that have different process models, different modes of control and different assignments of responsibilities and authorization for process operation and change management. Concerns about the incompatibilities between business processes that are to be employed in any exchange of entities shall be described prior to any active collaboration, unless it is intended that the collaboration be achieved through the use of agent negotiation or similar technology.

The description shall include the detailing of the process information and other entity exchange needs and the capabilities of each business entity, and the explicit identification of all relevant responsibilities and authorizations. The description shall also include the process incompatibilities that need to be resolved.

NOTE 1 Process interoperation is accomplished by resolving conceptual and any other differences between process information and other entity exchange needs and offerings, as well as finding appropriate technology solutions.

NOTE 2 Developing process interoperability means finding solutions to enable mapping, connecting, merging, and translations of possibly heterogeneous process models and applications. For interoperability reasons, these solutions are related to the points of interaction of the processes, not with the processes as a whole or with the internal details of the constituents of those processes. Developing process interoperability can also involve characterization of process capability in an externally accessible form to enable process discovery and utilization, thereby supporting interoperability rather than addressing the process concern directly.

Among the entities associated with process operation are process models. Process model interoperability shall be achieved by linking different process descriptions to form a collaborative process model, which could perform verification or simulation or execution of the overall process. These collaborative processes can use different process description languages and be defined in different process models for different purposes.

5.2.5 Business interoperability concerns

Business interoperability refers to the ability of enterprises to cooperate with partners for the conduct of business through necessary interactions of their respective organizations.

Business interoperation occurs when a particular business is understood and shared without ambiguity among interacting partners. Business interoperability is driven by value creation for participants and can rely upon less formal relationships in addition to contractual obligations. Often it is the case that agreements at lower organizational levels mirror those of business partners and thus appropriate business interoperability serves as a precursor for other interoperability concerns.

Business incompatibilities can arise for partners that cooperate or collaborate, but have different business models, modes of decision-making, methods of work, regulatory constraints, enterprise culture, commercial approaches, etc. Concerns about the incompatibilities between partner businesses involved in any exchange of entities shall be described prior to any active business interaction.

The description shall include the detailing of formal contracts, informal working arrangements, capabilities and capacity of each party to exchange necessary information and other entities, and the explicit identification of all relevant responsibilities and authorizations in partner organizations. The description shall also include the business incompatibilities that need to be resolved.

NOTE Business interoperation is accomplished by resolving conceptual and any other differences between business information exchange needs and offerings, as well as finding appropriate technology solutions.

5.3 Interoperability barrier viewpoint

5.3.1 Categories of interoperability barrier

The interoperability barrier viewpoint shall describe the incompatibilities and mismatches that obstruct the sharing and exchanging of information and other entities. Three categories of barriers shall be described:

— conceptual,

— technological,

— and organizational.

The notion of conceptual or technological comes also from engineering design where one distinguishes between conceptual design and technical design. A conceptual barrier describes incompatibilities that are independent from any technology, whereas technological barriers specify mismatches that are due to the implemented technology.

NOTE Many interoperability issues are specific to particular application domains, and require support for particular attributes, or particular access control regimes. In contrast, general barriers and problems of interoperability can be identified, and many of them are already being addressed (see References [15] and [21]).

5.3.2 Conceptual barriers

Conceptual barriers relate to the differences in the expression, definition, and understanding of exchanged items at various levels of abstraction, e.g. mismatched enterprise models of a company.

Conceptual barriers shall be detailed in terms of the syntactic, semantic, and semiotic incompatibilities of exchangeable items, particularly information and other knowledge assets.

— Syntactic incompatibility occurs whenever different people or systems use different expressions to represent information and knowledge. For example, service syntactic incompatibility occurs when there is a difference in the syntax used for the description of the service required and provided.

  NOTE 1 Standards such as ISO 19440 aim to overcome syntactic incompatibility by providing a neutral model to enable mapping between different enterprise models built using different forms of syntactic expression.

— Semantic incompatibility occurs whenever the meaning of exchanged items is not sufficiently similar. In this case, there is no clearly defined common meaning to enable unambiguous interpretation of the information content. For example, process semantic incompatibility occurs when there is a difference in the semantics used in different process modelling languages.

— Semiotic incompatibility occurs when participating entities interpret the exchanged items, concerning both artefacts and relationships, differently in different contexts. For example, business semiotic incompatibility occurs when there is a difference in the partners' business vision and culture, value expectations or operational concepts.

NOTE 2 Semantic refers to the meaning of concepts in general. Semiotic as used here refers to the interpretation of concepts. Semantic does not involve the presence of an observer or user, nor its own interpretation.

Conceptual barriers are the most significant barriers to interoperability because of the need for the exchange of entity content.

5.3.3 Technological barriers

Technological barriers relate to one or more technological discontinuities somewhere along the item exchange path. In the use of ICT to communicate and exchange information, a significant technological barrier for enterprise interoperation involves incompatible interfaces between the different systems, which can be enterprises, human-being interactions or computer systems. These incompatibilities often result from different choices among standardized technologies that prohibit the sharing and exchanging of information between the systems involved.

NOTE 1 Technological barriers can include exchange assurance barriers, such as the inability to validate the fact that what was sent is what was received, and that what was sent was actually provided by the assumed sender.

Technological barriers shall be detailed in terms of the technological incompatibilities that adversely affect the ability to exchange entities.

The following are examples of technological barriers:

— physical manifestations barriers, e.g. different part and product handling due to dimensions and materials of fixtures, magazines and packing materials;

— power conversion and consumption barriers, e.g. different line voltage and power transformation technology;

— material logistics barriers, e.g. different storage and transportation requirements;

— communication barriers, e.g. incompatibility of the protocols used to exchange information or to search and discover a service provider;

— information barriers, e.g. different techniques used to represent information, or incompatibility in the tools used to encode/decode the information being exchanged;

— infrastructure barriers, e.g. use of different incompatible middleware platforms, different database technologies and coding techniques, incompatible process execution engines and platforms, differences in ICT infrastructure support.

NOTE 2 Technological barriers are additional barriers with respect to conceptual barriers. This part of ISO 11354 primarily addresses technological barriers, and then focuses on the ICT characterization of those barriers and to solutions primarily in the manufacturing domain.

5.3.4 Organizational barriers

Organizational barriers relate to the allocation of responsibility and authority, and the execution or regulation of decision-making and operational activities. When responsibility in an enterprise is not clearly and explicitly defined, interoperation between two systems is more difficult or obstructed completely. Without defining who is authorized to create, modify and maintain exchange content, assurance of the integrity of data, processes, services, etc., is almost impossible. These barriers are related to human and organizational behaviour. Indeed, when two enterprises have different organizational structures (e.g. hierarchical versus matrix authority) and decision processes, mappings are likely to be needed before the two enterprises can interoperate.

The organizational barriers shall be detailed in terms of the incompatibilities of organizational structures, management techniques and policies implemented in the enterprises attempting to interoperate. The following are examples of organizational barriers:

— responsibility incompatibility occurs when interaction participants are unable to identify the person or organizational unit associated with an exchanged item (e.g. who is to be called if the data transmission is not received within the specified time frame?);

— authority incompatibility occurs when interaction participants are unable to identify the person or organizational unit capable of committing exchange resources or qualifying exchange results;

— decision-making incompatibility occurs when the decision processes of interaction participants have different time horizons or different decision parameters with respect to the exchange items;

— policy incompatibility occurs when enterprises have different and incompatible policies affecting areas of their interaction, e.g. different database management, different security policies or different policies for management of service provision;

— process organizational incompatibility occurs when enterprises have different process structuring mechanisms, configurations and managements, or different process granularities and scopes;

— regulatory incompatibility is a kind of barrier that involves interaction with a third party who controls or constrains some aspect of exchange authority; this control can dictate which items of exchange are necessary or required for a particular interaction between two enterprises.

NOTE Organizational barriers are additional barriers. Compared with conceptual barriers (centred on information problems) and technological barriers (associated with computational problems), organizational barriers often originate from human-related issues but have an impact on the interoperation of ICT systems.

5.4 Interoperability approach viewpoint

5.4.1 Categories of approaches

There are three approaches to achieve enterprise interoperability:

— integrated,

— unified,

— and federated.

The interoperability approach viewpoint shall state which of these three categories of approaches is being or will be used to address a specific problem of interoperability of entities within or between enterprises and provide further details about that approach, as described in 5.2.2 to 5.2.4.

NOTE These three approaches were first identified in ISO 14258, intended for withdrawal with integration of relevant content into ISO 15704.

5.4.2 Integrated approach

In the integrated approach a common form shall be used to represent the exchanged entities. This common form shall be sufficiently expressive to capture those details that affect interoperability of the items to be exchanged, rather than the process or system as a whole. The common form is not necessarily an International Standard, but needs to be agreed by participating enterprises in order to elaborate these entities and build systems accordingly.

EXAMPLE Examples of developing interoperability using an integrated approach are ISO 10303, ISO 19440 and OASIS/UNCEFACT ebXML[14].

The integrated approach assures consistency and coherence of the interoperating subsystems by focusing on the components that need to interact. These components are then designed and implemented using a common form (or standard) so that interoperability is seen as a designed-in quality. Interoperation between these various components is therefore obtained *a priori* without any interfacing effort. Subsystems that are integrated in this way have distinct and individual structure, behaviour, or boundaries, but their combined behaviour is perceived to be as one entity and is achieved by collaboration and coordination through the use of the common form.

5.4.3 Unified approach

In the unified approach, a common meta-model, which is applicable for the participating entities and used as a common reference to map existing models' syntax and semantics, shall be identified and detailed. This meta-model provides at least a reference vocabulary, but could be a complete ontology. Such a meta-model is not an executable entity. Instead, it shall provide a means for semantic equivalence to enable mapping between entities. Using this meta-model, a translation between the constituent entities is then possible. However, that translation might involve the loss of some information because the participating entities can have different extensions or instantiations of the same meta-model.

NOTE 1 The unified approach is particularly suitable when developing interoperability for collaborative or networked enterprises. To be interoperable with networked business partners, a new company maps its own model or system to the neutral meta-model without the necessity to make changes on its own model or system. This approach has an advantage over the integrated approach because of the reduced efforts, time and cost in implementation. It is also suitable for a situation where a large company needs to interoperate with SMEs. Normally an SME works with more than one large company; to interoperate with different companies, the unified approach can be a suitable solution in that it facilitates coordination without requiring conformance to potentially conflicting processes or environments.

NOTE 2 In the re-engineering situation, syntactic alignment can be achieved through a unified approach that uses a mapping function to create missing elements of the exchange items, but semantic alignment between partners can be very difficult. Therefore, re-engineering is more applicable to developing intra-enterprise interoperability.

5.4.4 Federated approach

In the federated approach, there is no sufficiently capable common form or meta-model to guide the interaction between enterprises that need to interoperate. The lack of capability is often related to different terminologies or methodologies that need to be resolved by business entity interaction. While there can be a common understanding between the business entities, in the federated approach, no business entity imposes their own models, languages and methods of work.

To establish interoperability, parties shall accommodate and adjust their operations. Interoperation can be supported by providing *a priori* information about the capabilities of the entities to be involved in the exchange or by employing agents to discover the needed information. Support for the *a priori* case can be provided by establishing entity capability profiles that hold syntactic and semantic information on both entity inputs and outputs. Interoperability can be established by mapping corresponding input and output information of the entities and identifying inconsistencies. Any remaining inconsistencies shall be resolved by manual interventions.

This approach is more suitable for peer-to-peer situations, where each enterprise has resources for negotiation and compromise. The approach is particularly adapted to virtual enterprises, where diverse companies combine their resources and knowledge to manufacture a product for a limited duration.

NOTE Using the federated approach to develop enterprise interoperability is most challenging. A main research area is development of a mapping factory that can generate on-demand customized "anybody-anywhere-anytime" mapping agents among existing systems. It is worth noting that a specific support for the federated approach is seen in entity profiles, which identify particular entity characteristics and properties relevant for interoperation (e.g. ISO 15745 and ISO 16100).

5.4.5 Applicability of approaches

All three approaches enable the establishment of interoperability between enterprises' systems. The federated approach is considered as the most challenging one for achieving interoperability. The choice depends on the context and requirements of interaction. When the need for interoperability comes from re-engineering existing entities within an enterprise, the integrated approach can be the most suitable because it does not necessitate fundamental changes in existing operational models. If the need for interoperability arises from a merger or long-term collaboration, the unified approach is a possible solution since the expense of establishing interoperability is amortized over the entire collaboration. The common meta-model across business entities facilitates semantic equivalence and reduces the need for cross-business entity interpretation of communication elements. Finally, the federated approach will yield the most satisfactory results for a short-term collaboration, ranging from a single transaction to a virtual enterprise, where a dynamic adaptation among business entities is achieved by an on-line negotiated agreement.

5.5 Example of relationships between interoperability viewpoints

Table 1 illustrates how interoperability concerns, barriers and approaches are interrelated for the example of an order (as a data object) being passed from one enterprise to another.

Table 1 — Example interoperability viewpoint relationships for order

Interoperability concern	Object exchanged	Example	Interoperability barrier	Mismatch	Interoperability approach		
					Integrated	Unified	Federated
Business	Data object	Order	Identification of responsibility and authority	Unknown authority	Align organization	–	–
Process	Data object	Order	Version control	Different time stamps	–	–	Identify relation
Service	Data object	Order	Object structure	Different element order	–	–	Order mapping
Data	Data item (file/element)	Order number	Semantic, syntax	Different structure or format	–	Ontology mapping	–

5.6 Representation of interoperability viewpoints

Interoperability concepts as presented above can be formally modelled using ontology techniques (see Reference [26]). Figure 2 illustrates a conceptual model representing the basic concepts of enterprise interoperability. The primary concepts, which are represented with their different aspects as subtypes, are the following:

a) interoperability concern,

b) interoperability barrier, and

c) interoperability approach.

The interoperability approach defines a relationship concerning the interoperating systems. These concepts provide a prerequisite for classifying or characterizing interoperability solutions. A solution shall be classified with respect to categories of concern, barrier and approach.

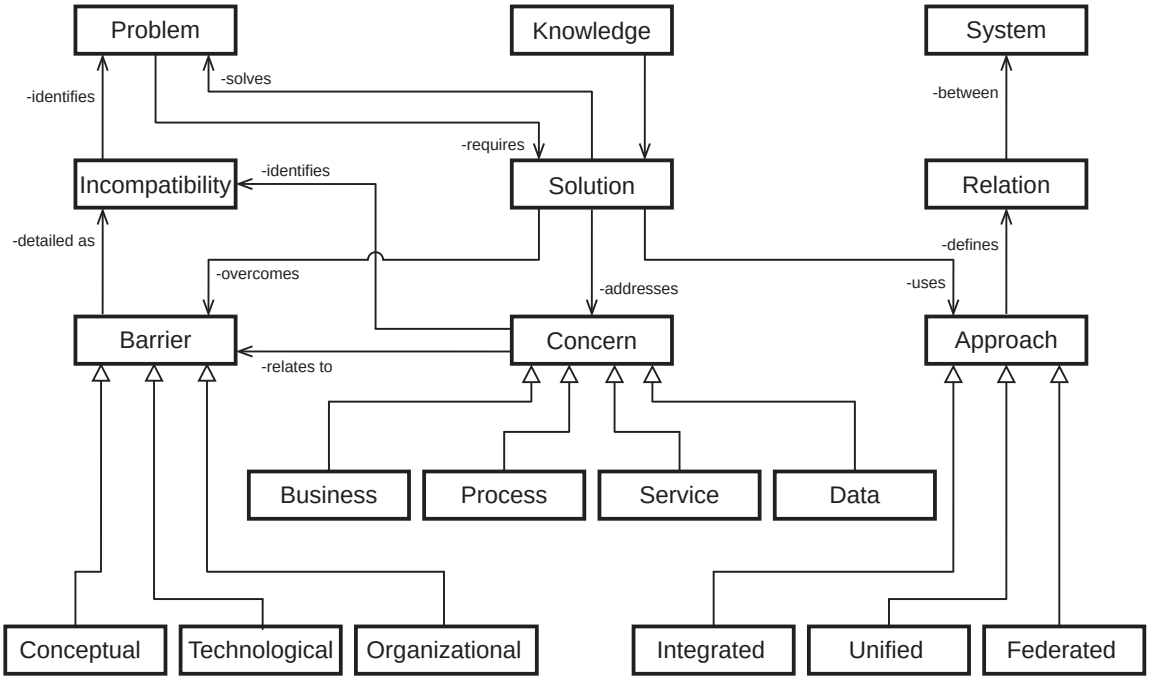


Figure 2 — Conceptual model for enterprise interoperability

6 Framework for enterprise interoperability

6.1 Framework as a structuring mechanism

The term “framework” refers to a mechanism that categorizes concepts from a particular domain. The FEI presented in this part of ISO 11354 provides a framework that structures the concepts and viewpoints relating to enterprise interoperability. The framework has three dimensions:

— interoperability concerns,

— interoperability barriers, and

— interoperability approaches.

The framework is also complemented by supplementary dimensions. Three supplementary dimensions (interoperability engineering, interoperability measurement and interoperability solutions) are defined in this part of ISO 11354 and others can be defined and added to the FEI.

6.2 Interoperability concerns and interoperability barriers dimensions

6.2.1 Categorization of interoperability barriers and concerns

Using the concepts, definitions and viewpoints presented in Clause 5, the first two dimensions of the FEI can be used to categorize different categories of barriers and concerns, as illustrated in Figure 3.

Interoperability barriers / Interoperability concerns	CONCEPTUAL	TECHNOLOGICAL	ORGANIZATIONAL
BUSINESS			
PROCESS			
SERVICE			
DATA			

Figure 3 — First two dimensions of the FEI

The categories shown in Figure 3 can be further detailed into subcategories, as shown in Figure 4, e.g. conceptual barriers into syntax barriers and semantic barriers.

Figure 4 gives three examples of classifying solutions into subcategories.

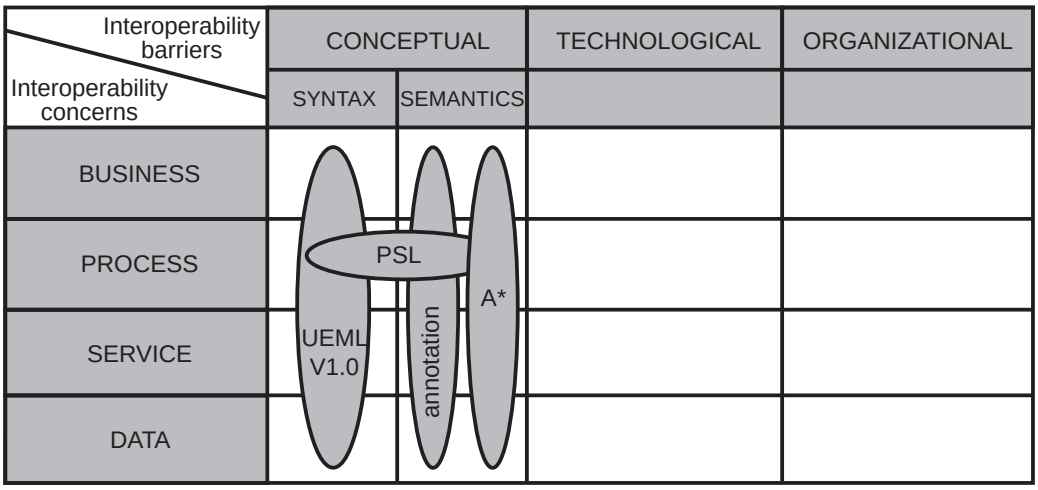


Figure 4 — Use of the framework to define the domain and to structure knowledge

6.2.2 Populating the FEI

Solutions are relevant to the resolution of interoperability difficulties if they contribute to overcoming one or more barriers. Such solutions can address more than one barrier and be associated with more than one concern. Figure 4 shows an example of how the FEI can classify solutions, and relate those to interoperability barriers. Figure 4 shows how PSL (see ISO 18629-1) contributes to overcoming both syntactic and semantic barriers for the process concern category only. Semantic conceptual solutions are provided by annotation and by the A* annotation tool (a development from ATHENA[11]).

NOTE The three categories of barriers (conceptual, technological and organizational) can impact interoperability at all four concern categories. Conceptual and organizational barriers can be considered as more important in the business and process categories, while technological barriers (e.g. barriers due to the use of ICT) can impact data and service categories more.

6.3 Interoperability approaches dimension

The third dimension of the framework provides a representation of the three interoperability approaches described in 5.4. The interoperability approaches dimension provides a means for capturing and structuring interoperability knowledge and solutions with more precision. Using the example shown in Figure 4, the language of PSL can contribute to overcoming conceptual barriers (both syntax and semantics) concerning processes through a unified approach.

6.4 Dimensions of the FEI

6.4.1 Representation of the FEI

The three dimensions of the FEI are illustrated in Figure 5.

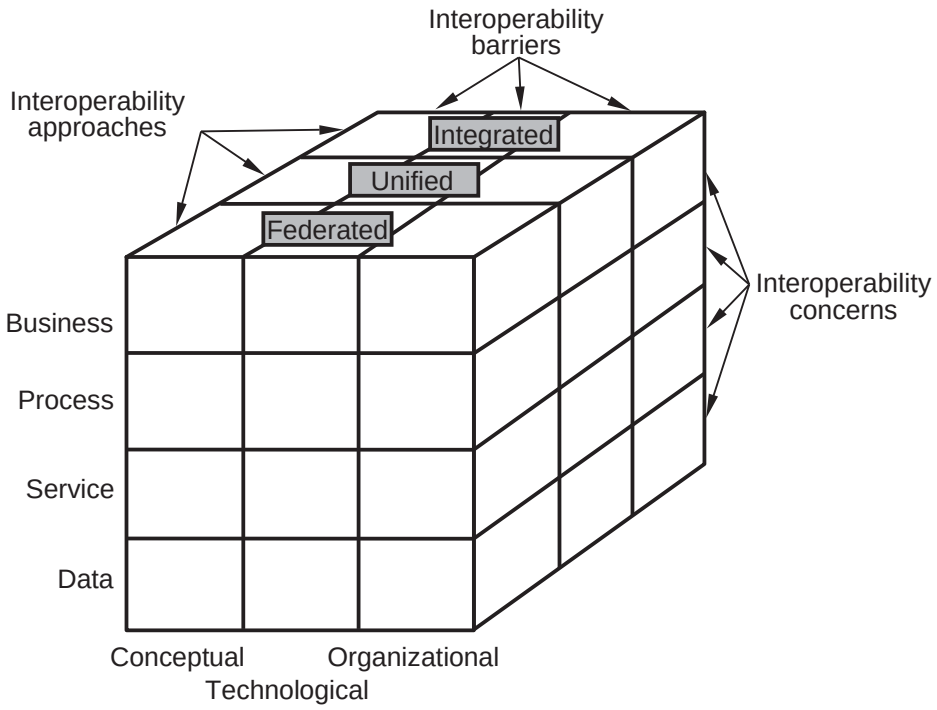


Figure 5 — Three dimensions of the FEI

6.4.2 Example usage of the framework

Figure 6 illustrates the classification of the PSL solution (see ISO 18629-1) in the framework.

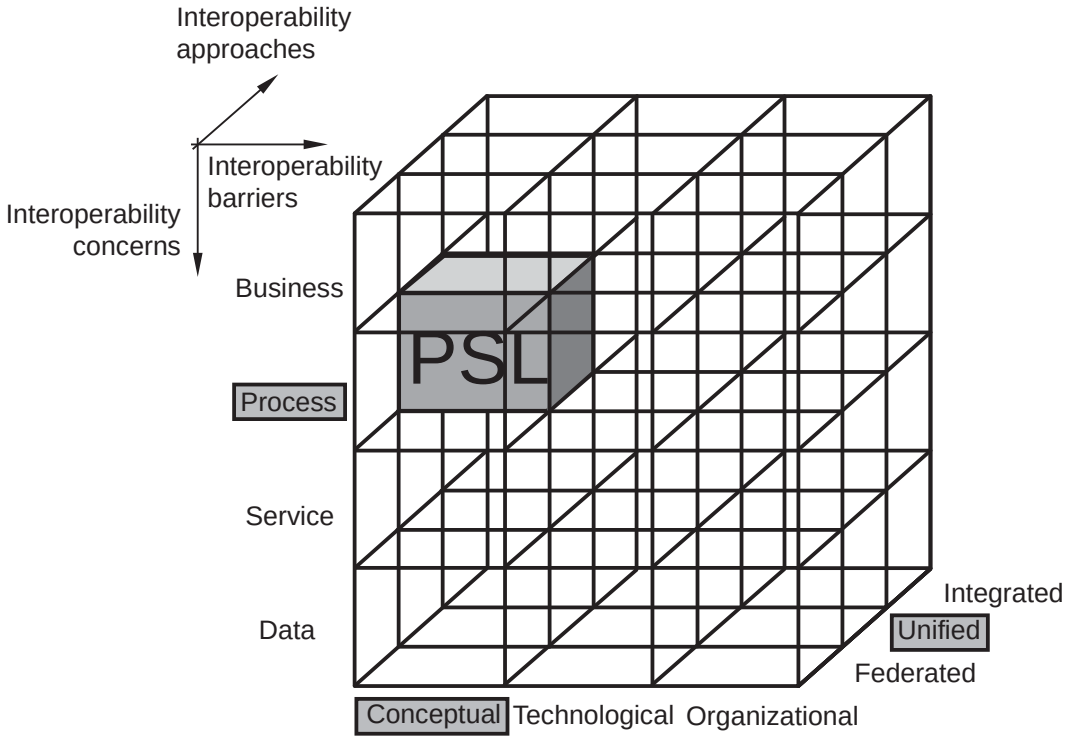


Figure 6 — Classification of PSL in the framework

To help in capturing relevant knowledge, as well as partial or complete solutions, and classifying those within the framework, a template can be used to describe the barriers and relevant knowledge/solutions. Table 2 illustrates a simplified example of using the template to describe the PSL solution.

Table 2 — Template and simplified example of collected knowledge for the PSL solution

Name of solution	Process Specification Language (PSL)
Interoperability concern	Process level
Interoperability barrier	Conceptual (syntax and semantics)
Interoperability approach	Unified approach
Interoperability problem	Different models use different process languages and are not interoperable
Interoperability knowledge	Apply a neutral PSL and related ontology as a meta-model to enable mapping between different process models
Example (optional)	
Remarks	Initially proposed by Mark Fox and Mike Gruninger at the University of Toronto, further developed at NIST, now moved to standardization at ISO level.
References	ISO 18629-1:2004

6.5 Supplementary dimensions for interoperability

6.5.1 Categories of supplementary dimensions

Supplementary dimensions characterize aspects of solutions that can differ for each of the three interoperability approaches. The following three are defined in this part of ISO 11354:

— interoperability engineering;

— interoperability measurement;

— interoperability solutions.

Other supplementary dimensions may be defined by the user for particular purposes.

6.5.2 Supplementary dimension for interoperability engineering

This dimension identifies a set of life cycle phases associated with the engineering of interoperability between two enterprises (or any two business entities). These can be based on the life cycle phases defined in ISO 15704:2000, Annex A. Figure 7 illustrates this supplementary dimension using just three of those life cycle phases, as follows:

a) requirements definition;

b) design specification;

c) implementation.

In using this supplementary dimension in an interoperability project, the requirements definition phase shall identify how to address barriers to interoperability that exist between two enterprises (or business entities) and the interoperability concerns. The design specification phase shall develop interoperability solutions to overcome the barriers. The implementation phase shall implement and test the solutions.

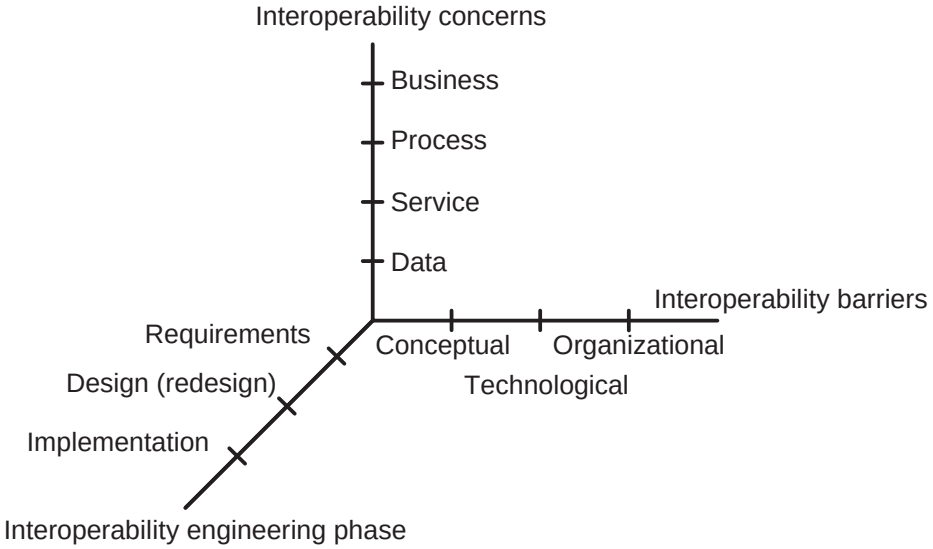


Figure 7 — Supplementary dimension for interoperability engineering

6.5.3 Supplementary dimension for interoperability measurement

The extent of interoperability is a measure that characterizes the capability for interoperation between two enterprises (or business entities). Three categories of interoperability measurements shall be identified, as illustrated in Figure 8:

a) potentiality measurement;

b) compatibility measurement;

c) performance measurement.

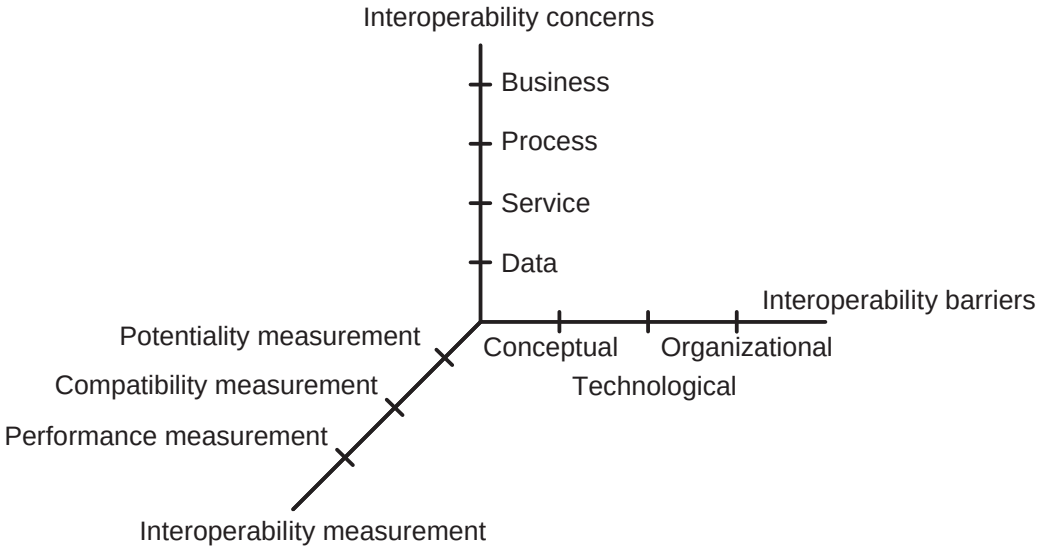


Figure 8 — Supplementary dimension for interoperability measurement

The potentiality measurement shall identify a set of enterprise or system properties (e.g. flexibility, openness, modularity) that express the general level of interoperabilityof the enterprises.

This measurement shall be performed on one enterprise or business entity without knowing its interoperation partner. The objective of this measurement is to assess the general potentiality of a system to overcome possible barriers.

NOTE The future ISO 11354-2 will specify a maturity model for enterprise interoperability that can be used to assess an enterprise's general level of interoperability.

The compatibility measurement shall identify the extent to which barriers exist between interoperating business entities. This measurement shall be performed during the engineering stage when the partner of the interoperation is known, e.g. when systems are re-engineered in order to establish interoperability.

The performance measurement shall evaluate interoperations between two cooperating enterprises. This measurement shall be performed during the test or operation phase, for criteria such as cost of exchange, delay in response and quality of service.

Each category of measurement shall be evaluated with local coefficients that are then aggregated in order to determine a global coefficient.

6.5.4 Supplementary dimension for interoperability solutions

This part of ISO 11354 identifies two categories of engineering solution, as illustrated in Figure 9:

a) conceptual, and

b) technological.

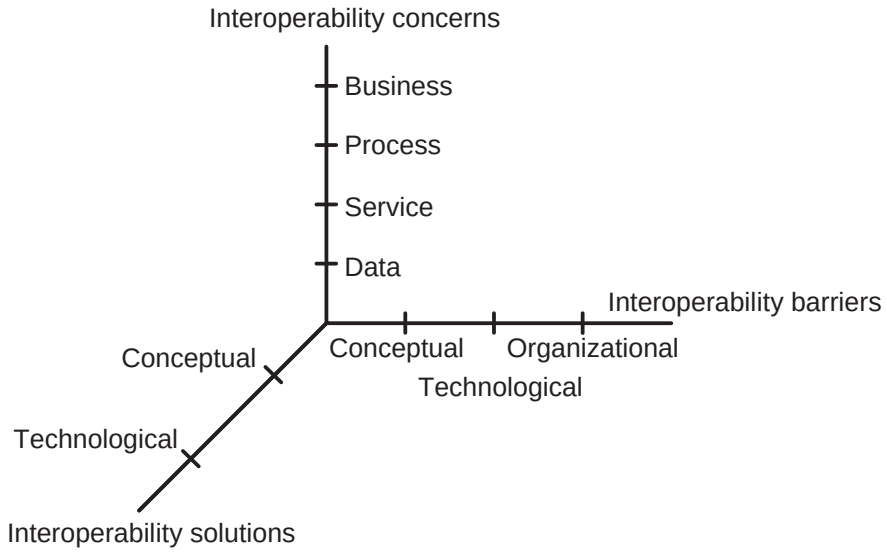


Figure 9 — Supplementary dimension for interoperability solutions

A conceptual solution describes the ideas that enable one to solve a problem without specifying how to concretize or implement the ideas. Such a conceptual solution can also be a conceptual representation of an existing technical solution. In this case, only generic aspects of the solution (e.g. functions) are filtered and represented without specific technological details.

A technological solution describes the technology implemented for removing the identified barrier. For a given conceptual solution, there can exist several different technologies to implement the solution. The technology choice is made at the technical design stage.

NOTE While one solution to interoperability might be a change in organizational structure for one or more partners, this solution is not considered an engineering discipline solution within this part of ISO 11354.

With this dimension, it is possible to classify interoperability knowledge and solutions in the framework in a more precise way. For each category of approach and each category of barrier (conceptual, technological, organizational), solutions can be conceptual, technological or both. For example, the semantic annotation method (a conceptual solution) and the A* tool developed in the ATHENA project[11] (a technological solution) shown in Figure 4 are both ways to remove semantic barriers concerning all four concern categories.

6.6 Example of using the FEI

This subclause provides two examples for which using the FEI is or is not appropriate. A more detailed example of using the FEI is given in Annex B.

EXAMPLE 1 Two enterprises, A and B, exchange order and invoice data. The two systems involved are not fully interoperable because of some semantic mismatch. In the exchanged data files, the two enterprises use different terms to represent the same objects. Table 3 shows examples of the semantic mismatch.

Table 3 — A semantic mismatch of data

Enterprise A	Enterprise B
order	customer order
due date	delivery date
product	item
price	unit price
total amount	price

This problem is an interoperability problem that is classified within the FEI, as shown in Table 4.

Table 4 — Classification of this semantic mismatch

Interoperability concern	data
Interoperability barrier	conceptual (semantic)
Interoperability solution	semantic annotation of data using ontology

EXAMPLE 2 Two enterprises, A and B, have a collaboration partnership. Enterprise B works for enterprise A as a subcontractor to provide a mechanical part. The problem encountered is that the delivery delay required of enterprise B by enterprise A is often too short, because it is only at the last minute that enterprise A knows if the subcontracting is needed. The production planning system used in enterprise A is not adequate to predict the needs of subcontracting and to provide the needed data. Evidently, this is an internal production planning problem that is only concerned with enterprise A. This problem is therefore not an interoperability problem and so cannot be positioned within the FEI.

Annex A
(informative)

Mapping of existing interoperability frameworks to this part of ISO 11354

Six existing interoperability frameworks (AIF[10], BIF[13], IDEAS[18], EIF from iDABC[15], nehta[24] and LISI from the US DOD[22]) have been compared to the FEI developed in this part of ISO 11354. Comparison has shown one fundamental difference between the first six and the FEI: barrier and concern dimensions are defined only in this part of ISO 11354. None of the other frameworks identify the interoperability problems explicitly, but rather they define areas of solutions, as shown in Table A.1.

A second difference is in the way each addresses interoperability. Whereas this part of ISO 11354 identifies three approaches (integrated, unified and federated), ATHENA in its AIF focuses on solutions through integration only and defines categories of solutions in its BIF. EIF and nehta define aspects and types of interoperability that cover the same areas, with a particular emphasis on the information semantics for the iDABC EIF. Levels of interoperability are defined by both IDEAS and the LISI, with the latter restricting itself to information systems only.

Solution types are identified for all frameworks, however, with varying degrees of detail, as shown in Table A.2. The FEI defined in this part of ISO 11354 identifies only a very high level of solution types (conceptual and technological) and is similar in this respect to the LISI, which uses procedures, infrastructures, applications and data for solution types in the information system domain. The most detailed definition of solution types is provided by IDEAS, which details its first level further (i.e. in terms of business, data, communication and application) and defines a second level of solution types for each first level solution type. However, there is a close relation to the dimension of concern defined in this part of ISO 11354.

As shown in Table A.3, almost all frameworks (the only exception being EIF) identify what are referred to in this part of ISO 11354 as supplementary dimensions. These dimensions are of two kinds: quality related and engineering related. Whereas the quality-related dimensions all define very similar items, the engineering-related dimensions define phases of engineering life cycles (FEI and BIF) or interoperability profile (AIF).

In Tables A.1 to A.3, the AIF column is split into two subcolumns in order to reflect different interpretations provided in the literature.

Table A.1 — Comparison of interoperability framework structures

FEI	AIF		BIF	IDEAS	EIF	nehta	LISI
Barriers							
Conceptual Technological Organizational							
Concern							
Business Process Service Data							
Approaches	**Types of integration**		**Outline**	**Levels of interoperability**	**Aspects**	**Types of interoperability**	**Levels of IS interoperability**
Integrated Unified Federated	Conceptual Technical Applicative		Categories Life cycle Levels of business interoperability Contingencies	Business Knowledge Application Data Communication	Organizational Technical Semantic	Organization Technical Information	4 – Enterprise 3 – Domain 2 – Functional 1 – Connected 0 – Isolated

Table A.2 — Comparison of interoperability frameworks solutions

FEI	AIF		BIF	IDEAS	EIF	nehta	LISI
Conceptual	**Conceptual integration**		**Categories**	**Business**	**Organizational interoperability**	**Organizational interoperability**	**Procedures**
	Concepts Models and metamodels Languages	Interoperability reference architecture	Management of external relationships Employees and culture Collaborative business processes Information systems	Decisional model Business model Business processes	Public services for citizens Public services for business	Business processes Standards plan Security policy Privacy	
Technology	**Technical integration**		**Contingencies**	**Data**	**Technical interoperability**	**Technical interoperability**	**Infrastructures**
	Modelling tools Execution environments	Interoperability support infrastructure Technical architecture	Internal contingencies External contingencies	Product data Process data Knowledge data Commerce data		Interoperability architecture Standards catalogue (Certification processes)	
	Applicative integration			**Application**	**Semantic interoperability**	**Information interoperability**	**Applications**
	Methodologies Use cases Reference examples	Best practice Guidelines Handbooks Interoperability methodology		Solution management Workspace interaction Application logic Process logic		Foundations Structures Value domain Assemblies	
				Knowledge			**Data**
				Organization roles Skills/competencies Knowledge assets			
				Communication			

Table A.3 — Comparison of interoperability frameworks supplementary dimensions

FEI	AIF		BIF	IDEAS	EIF	nehta	LISI
Measurement			**Levels of business interoperability**	**Quality**			**Assessment process**
Potentiality Compatibility Performance			Fully interoperable Qualified Moderate Minimum None	Availability Portability Performance Security Scalability Evolution		Certification processes	Interoperability profiles Interoperability metrics Interoperability matrices Comparison table Architecture products
Engineering	**Application Interface Protocols**		**Life cycle**				
Requirements Design implementation	Domain profiles	CPD profiles e-Procurement profiles PPM profiles SCM profiles	Approach Deploy Review and assess				

Annex B
(informative)

Example of use of FEI to identify and categorize interoperability barriers, knowledge and solutions

Current interoperability solutions are rather fragmented because they were developed by various institutions in various contexts for various purposes. Most of them were not dedicated to interoperability at large, but contribute in different degrees to improve interoperability. Moreover, it is difficult to relate these solutions precisely to the types of interoperability barriers they can solve. Consequently, classifying and structuring available solutions for interoperability into one consistent framework for easy reuse becomes an important challenge in developing interoperability.

In accordance with the three dimensions of FEI described in this part of ISO 11354 (interoperability concerns, interoperability barriers and interoperability approaches), interoperability solutions can be positioned within the framework and related to barriers, so that they can be more easily searched and used to solve interoperability problems. A methodology, service or product is considered to be an interoperability solution if it can overcome at least one barrier for one concern using one of the three approaches (integrated, unified, federated).

Figure B.1 from the INTEROP NoE project shows a snapshot from an interoperability solution repository implemented in accordance with the FEI using the METIS tool[23]. The example shows linkage of a specific barrier (technological) and a specific interoperability concern (data) to a specific solution (FRISCO[17]) and the particular approach (federated approach).

This knowledge repository model supports the analysis of the knowledge pieces collected. The solutions container has the pieces of knowledge that can be further described in detail using a template.

The complete modelling of the set of solutions identified in workpackage DI, Domain of Interoperability INTEROP NoE[20], and their relationships are shown in Figure B.2. The density of connecting lines in Figure B.2 illustrates the complexity of these relationships and hence the need for a tool to assist the user in identifying knowledge relevant to particular concerns and barriers.

The model helps in easily understanding where the knowledge can be useful to overcome interoperability barriers and to identify the areas where further work is needed. The collected knowledge pieces address all levels of the FEI.

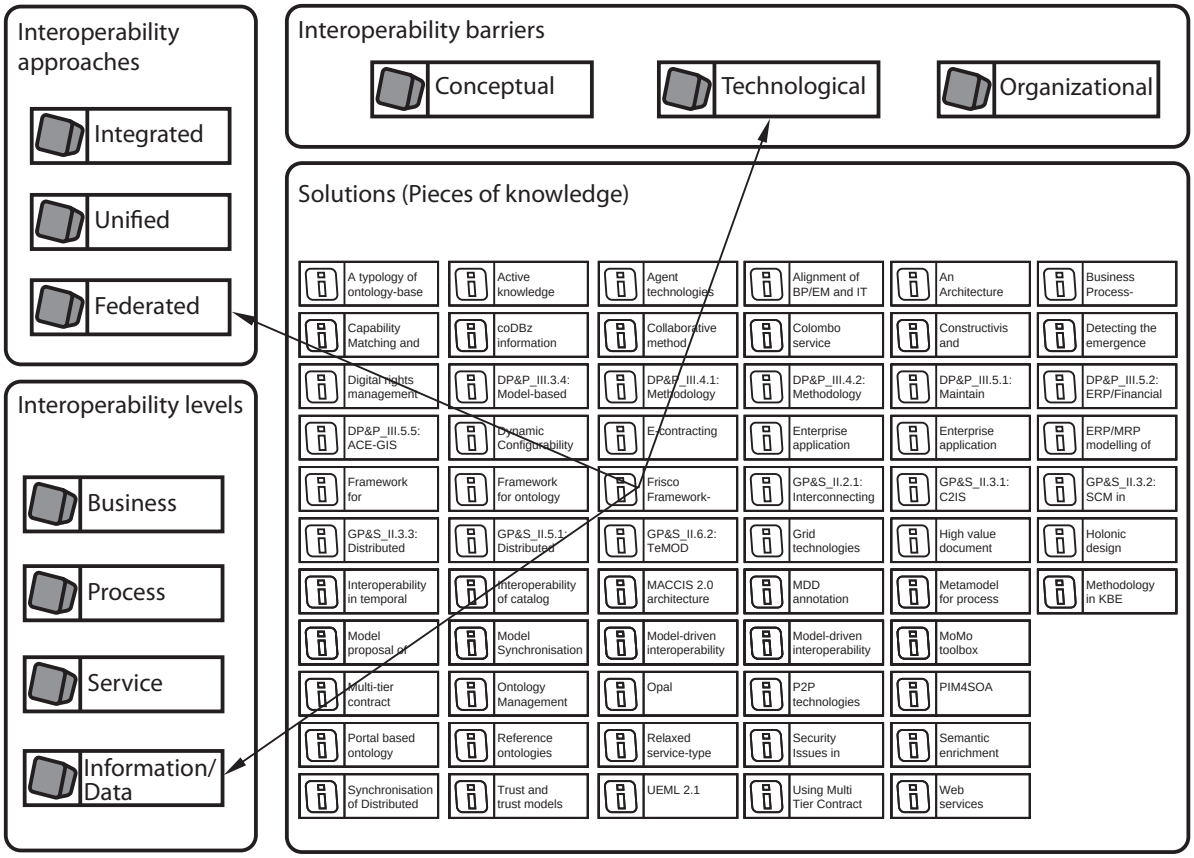


Figure B.1 — FEI and collected solutions implemented in Metis tool

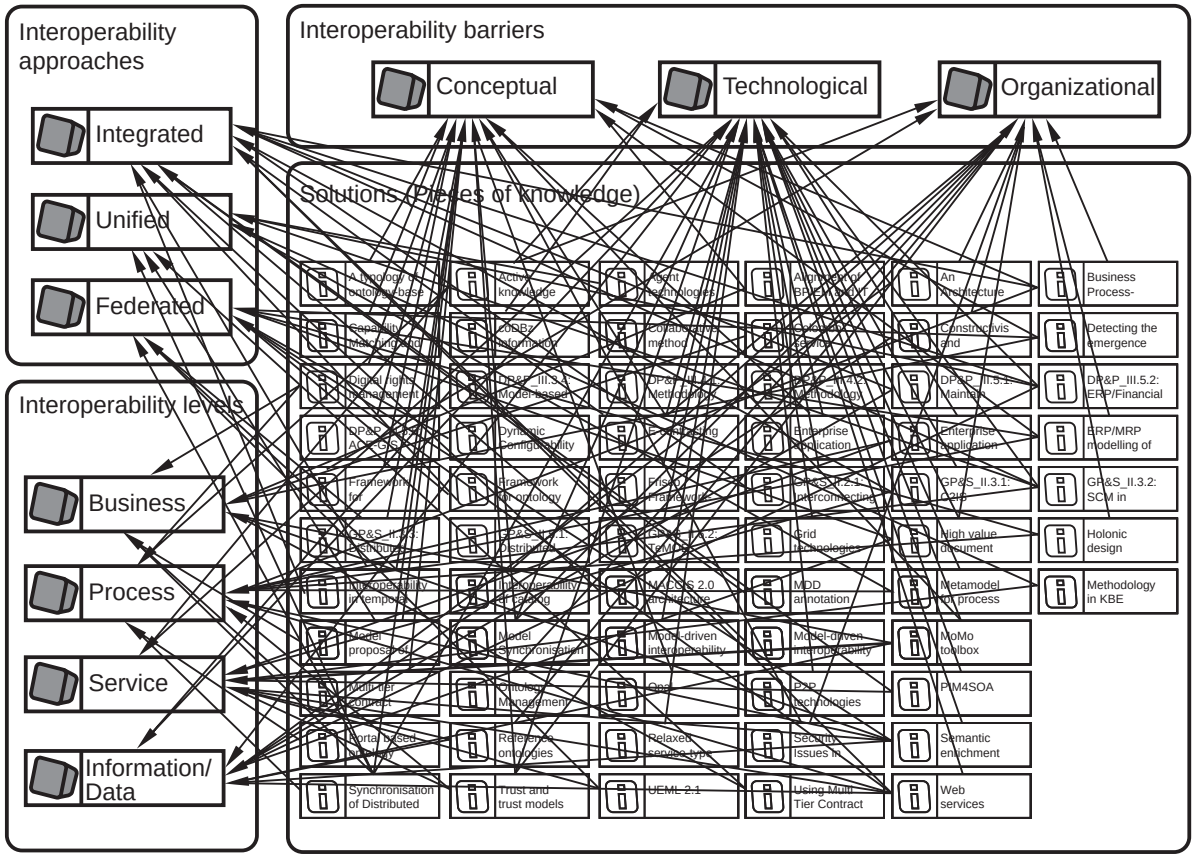


Figure B.2 — Classification of knowledge for overcoming interoperability barriers

Specific queries may be run on the knowledge model. The result of the query can be shown as a filtered view of the model, where only the objects and relationships of interest are highlighted. Two examples are given below:

— Figure B.3 shows a simplified example of a query to find the technologies in the “process concern, technological barrier” area of the FEI;

— Figure B.4 shows a simplified example of a query to find the concerns and barriers for which a specific technology [Platform Independent Model for Service-Oriented Architecture (PIM4SOA)[25]] can provide solutions, as characterized by the template description given in Table B.1.

Queries can be performed to support any additional analysis of the enabling technologies that could address concerns held by different stakeholders.

The model of the interoperability repository is not only aimed at classifying knowledge in accordance with the FEI, but is also a support for potential users to search and find solutions when their interoperability barriers and concerns are identified. Publishing the collected interoperability knowledge and associated FEI on the World Wide Web could enable a wider dissemination of available solutions and facilitate access to these solutions.

Figure B.4 shows that one solution can cover more than one interoperability concern (here process and service) and contribute to overcoming more than one interoperability barrier (in this example: conceptual and technological barriers). In some cases, an interoperability solution might be implemented using more than one approach. For example, PIM4SOA can be used as an integrated approach for developing enterprise model interoperability. It can also be used as a neutral metamodel (unified approach) to enable mapping of two enterprise models built using two different languages.

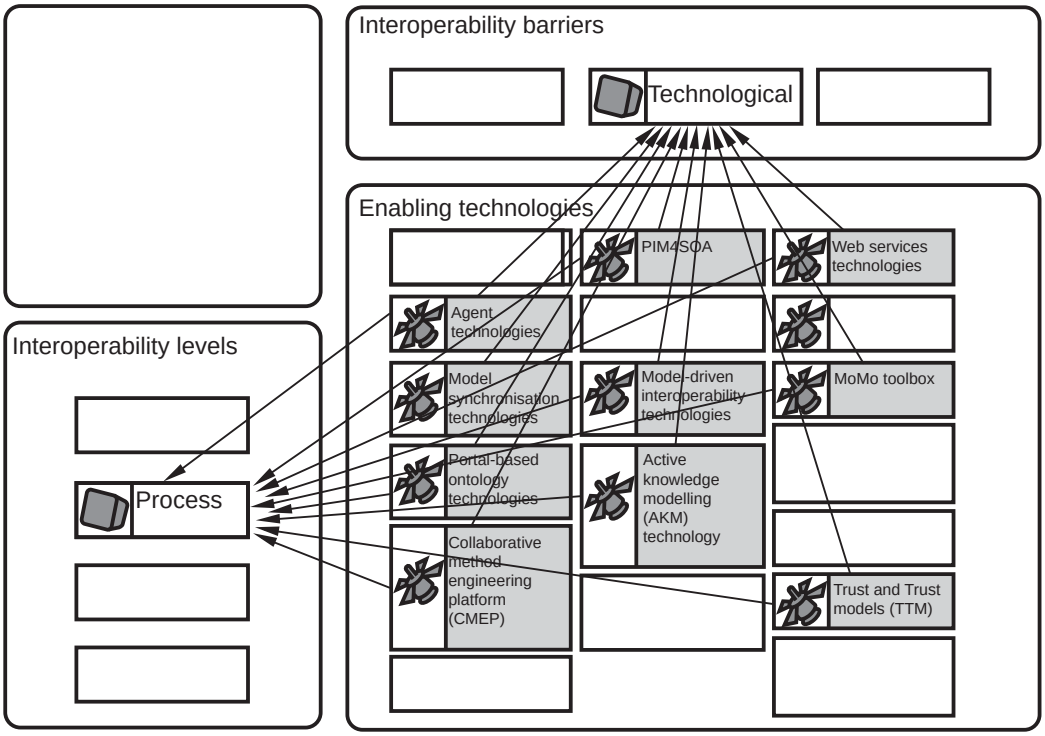


Figure B.3 — Highlighting technologies for the <process concern, technological barrier>

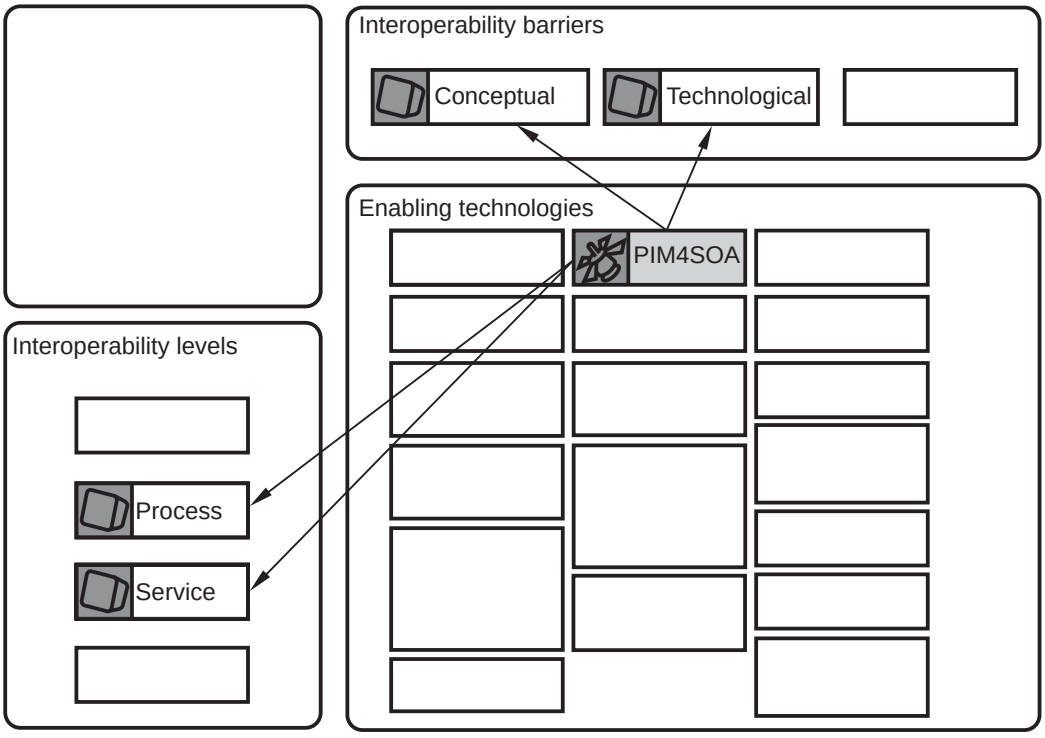
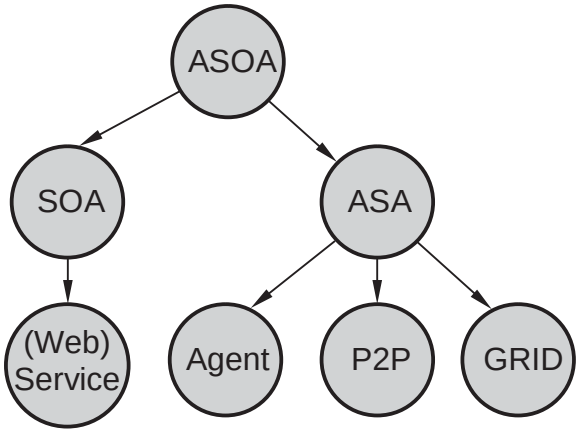


Figure B.4 — Highlighting the concerns and barriers addressed by the PIM4SOA technology

Table B.1 — Interoperability analysis of PIM4SOA

Name of solution	Platform Independent Model for Service-Oriented Architecture (PIM4SOA)
Interoperability concern	PIM4SOA addresses interoperability primarily at the service level, but also includes process aspects.
Interoperability barrier	PIM4SOA addresses the conceptual and technological interoperability barrier. It aims to define platform neutral modelling language constructs that can be used to design, re-architect and integrate ICT infrastructure technologies supporting service-oriented architecture (SOA).
Interoperability approach	Unified approach
Interoperability problem	The concept of SOA has grown in importance during these last years. Enterprises typically view SOA as an IT solution and often the focus is on the technologies involved. The PIM4SOA has the following goals: — The PIM4SOA model aims to bridge the gap between the business analysts and the IT developers and support mapping and alignment between enterprise and IT models. — The PIM4SOA model aims to define a platform neutral abstraction that can be used to integrate and define mappings to web services, business processes, agents and P2P execution platforms.
Interoperability knowledge	PIM4SOA aims to integrate SOA with adaptive software architecture (ASA) to form an advanced service-oriented architecture (ASOA), as illustrated in the figure below.  The PIM4SOA model addresses four different aspects of SOA: — service aspects: services are an abstraction and an encapsulation of the functionality provided by an autonomous entity; — information aspects: information aspects are related to the messages or structures exchanged, processed and stored by software systems or software components; — process aspects: processes describe sequencing of work in terms of actions, control flows, information flows, interactions, protocols, etc.; — non-functional aspects: extra-functional qualities that can be applied to services, information and processes.
Examples of use (optional)	
Remarks and comments	The PIM4SOA work was initiated in the ATHENA project. See PIM4SOA website (http://pim4soa.sourcefourge.net/) and Reference [12]. In addition to validating the PIM4SOA metamodel within the INTEROP community, the intention is also to integrate and align PIM4SOA with other ICT infrastructure technologies not covered in ATHENA, e.g. GRID computing.
References	PIM4SOA website (http://pim4soa.sourcefourge.net/) ATHENA A6, Model-Driven Interoperability, ATHENA IP, Working Document WD.A6.5.1, 2005

Annex C
(informative)

Guideline for using the FEI in an interoperability engineering project

C.1 Purpose

This annex aims to provide a methodological guideline on how to use the FEI in an interoperability engineering project. It is not intended to present a detailed operational methodology but only basic methodological concepts and principles so that such a methodology can be developed.

The FEI categorizes and structures interoperability concepts, while an enterprise interoperability methodology identifies and structures tasks to carry out an interoperability engineering project following an engineering life cycle. The main phases of interoperability engineering and associated tasks as well as the links to the FEI are shown in Figure C.1.

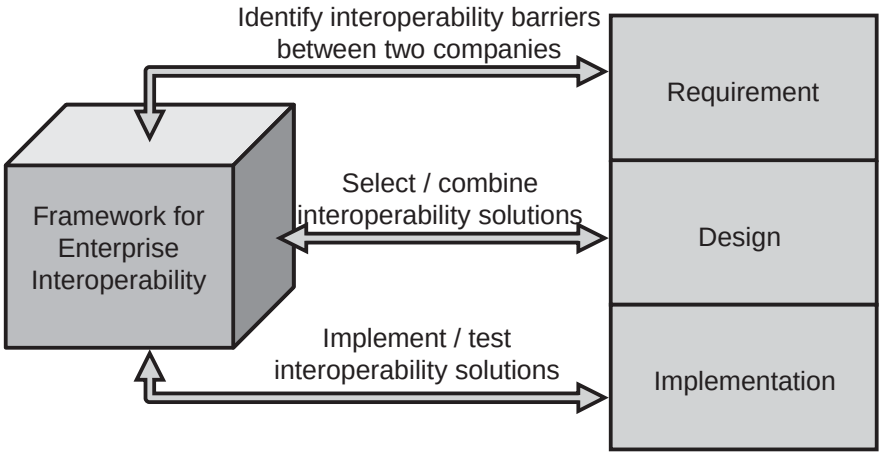


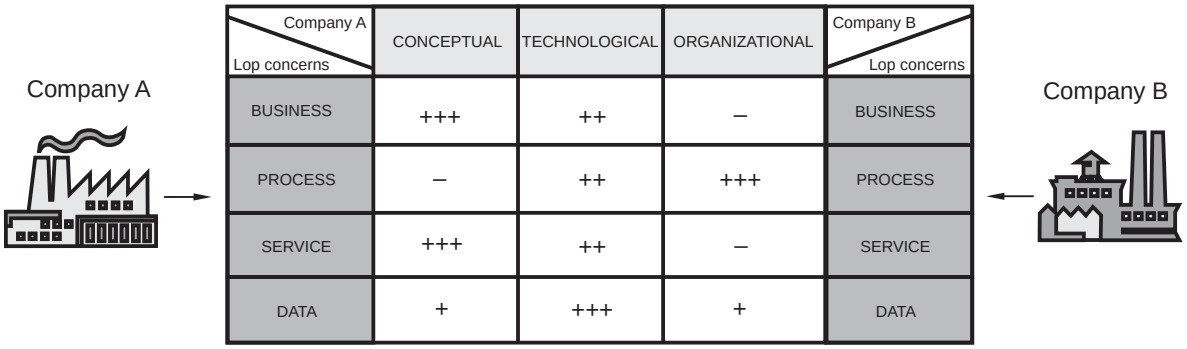
Figure C.1 — Interoperability engineering phase and the FEI

C.2 Identification of interoperability barriers

Using an enterprise interoperability engineering life cycle, an interoperability project starts at the problem identification and requirements definition phase. The objective is to analyse the existing situations of the companies and to identify existing interoperability barriers between the two companies (or two systems). At this phase, it is also necessary to define the extent of interoperability to be achieved.

The most crucial task is to analyse interoperability problems in order to identify interoperability barriers. This task is supported by the FEI (interoperability concerns and interoperability barriers dimensions) by evaluating compatibilities between the company in question and its interoperation partner. As an example, Figure C.2 provides an illustration of how barriers identified at the moment when company A and its partner company B wish to establish interoperability might be represented.

NOTE Identifying interoperability barriers pertains only to those “things” that need to be shared and exchanged between two systems/companies. Interoperability requires a common basis for those elements. Typically, not all of the information managed by two systems is shared. Therefore, interoperability requires identifying the shared elements and possible barriers for the exchange between the partners.



Key

+++ important barrier between the two companies

++ less important barrier between the two companies

\+ weak barrier between the two companies

– no barrier between the two companies

NOTE For each significant barrier, further details will be documented.

Figure C.2 — Compatibility measure performed at the beginning of the project

C.3 Search for interoperability solutions

With barriers identified, a search is made for possible solutions, or solutions are generated at the design phase, to overcome the barriers and solve interoperability problems. This task is supported by the FEI via the interoperability knowledge repository where existing knowledge and known interoperability solutions have been captured and structured.

The design phase is usually split into two subphases: conceptual design and technical design. The FEI contains both conceptual and technological solutions. Conceptual solutions are independent of technology to use for implementation. Given one conceptual solution, there can exist several technologies for implementation. The interoperability solutions dimension enables further classification of the solutions in accordance with these two criteria (see Figure C.3).

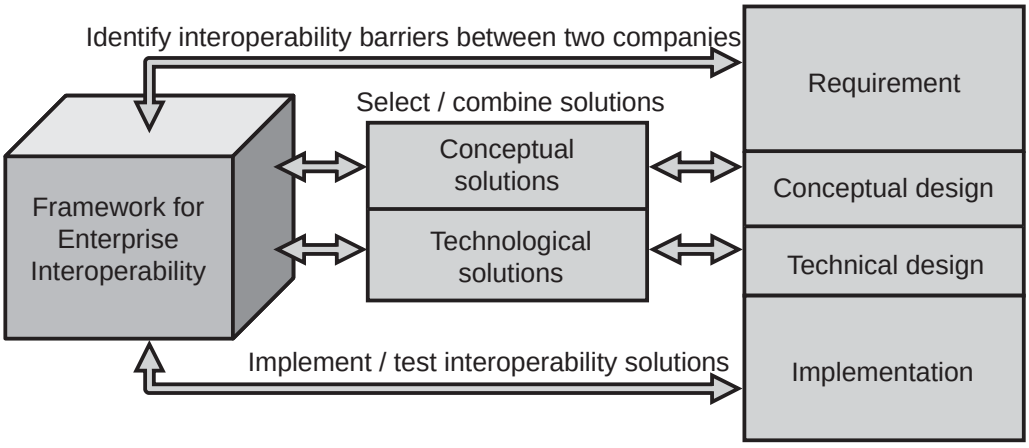


Figure C.3 — Solutions categories of the FEI and interoperability engineering phase

Considering the conceptual and technical solutions separately enables comparison and choice among several available technologies for implementation. It also facilitates technology providers in developing various technological solutions in accordance with conceptual specifications that are more stable compared with rapid evolution or changes in technology. Table C.1 shows an example of documenting conceptual and technology solutions using a template.

Table C.1 — Conceptual versus technological solutions to overcome a barrier

Template elements	Description
Interoperability concern	Data
Interoperability barrier	Conceptual barrier – incompatible syntactic and semantic representation of data at each interacting partner
Interoperability problem	Different models adopted by the companies makes data exchange difficult as enterprises cannot exchange their data automatically
Interoperability approach	Unified approach – using a predefined ontology to perform mapping
Conceptual solution	Annotation of proprietary models in accordance with common ontology to enable data reconciliation
Technical solution	Technical solutions developed by ATHENA A3 project: WSDL Analyzer tools

C.4 Test and implement interoperability solutions

After the solution(s) have been constructed and implemented, tests and measurement need to be done to verify that barriers are removed effectively using the proposed solution(s) and that the interoperability performance achieved satisfies requirements. If the targeted interoperability is not met, or in some cases the interoperability is improved but there still exist some incompatibilities, iterations are required to adapt the solution or to use other solutions until all barriers are completely removed and the targeted interoperability performance is achieved.

During an enterprise interoperability engineering project, the interoperability measurement dimension enables a more precise characterization of the following:

a) the general capability to interoperate (potentiality measurement),

b) the ability to interoperate with a specific known partner (compatibility measurement), and

c) the ability to meet the performance of interoperation with the known partner (performance measurement).

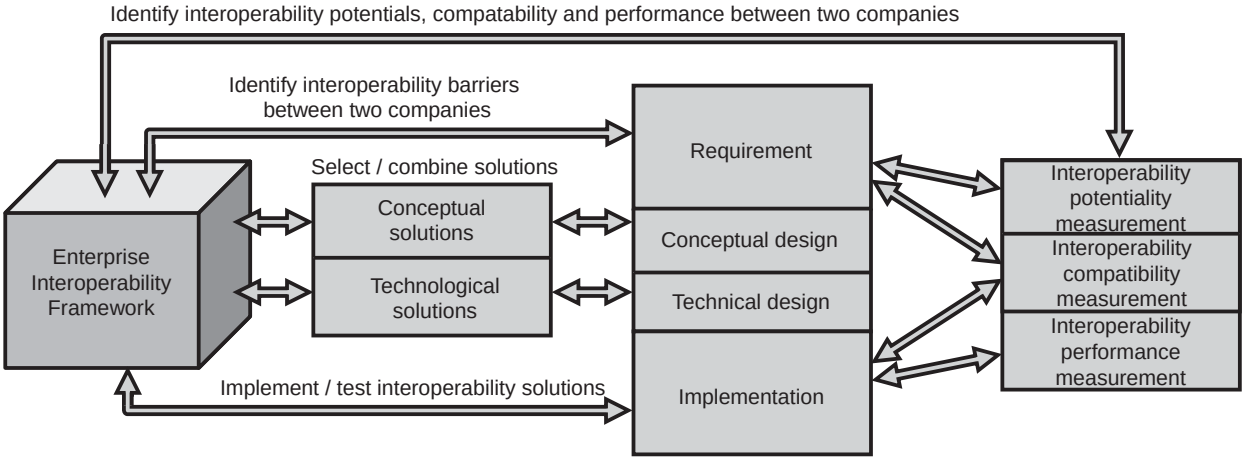


Figure C.4 — How the FEI supports interoperability measurements

As illustrated in Figure C.4, using the FEI, performance measurement is to be done during the test in collaboration with the partner and during the implementation and operational phase.

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