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A framework proposal for seamless interoperability in a collaborative networked environment

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ABSTRACT

The advances in information and communication technologies and economic factors impelled organizations to engage in new forms of collaboration, such as collaborative networks. They require adequate frameworks, architectures, tools and platforms to support interoperability among heterogeneous and geographically distributed organizations. Despite the high number of research projects in this area, existing tools and infrastructures, this objective has not been totally achieved. The aim of this research work is to advance the research in the area of interoperability in collaborative networks. A conceptual framework towards seamless interoperability in a collaborative–competitive economic networked environment is described, which comprises six elements: (1) a messaging service; (2) a collaboration profile/agreement definition and management service; (3) five clusters of collaborative activities; (4) a centralized repository; (5) a set of business documents and a set of contracting documents; (6) a performance assessment service. The functionality of the conceptual framework proposed is illustrated with a real implementation case targeting the footwear industry. The proposed conceptual framework is then compared with relevant e-business frameworks.

1. Introduction

Advances in information and communication technologies (ICTs), the increasing adoption of the Internet and turbulent market and economic conditions impelled organizations to examine their strategies and engage in new forms of collaboration, such as collaborative networks (CNs). As a consequence, businesses have migrated from traditional practices to e-business (e.g., [1,2]).

The CNs consist in heterogeneous and geographically distributed organizations with different competences, but symbiotic interests, which join and efficiently combine for a determined period of time their most suitable skills and resources to achieve a common objective (e.g., [3,4]). They require adequate technologies and ICT platforms to assure seamless interoperability among their member organizations.

Several reference models, frameworks, tools and ICT platforms supporting (or claiming to support) seamless interoperability in a collaborative–competitive economic networked environment (CCENE) have been developed. Nevertheless, this objective has not been totally achieved (e.g., [2,5–7]). Causes are diverse, and include: heterogeneity and lack of resources (e.g., [8]); lack of a generally accepted definition of interoperability (e.g., [9]); inadequate implementation, poorly managed risks and requirements. This is also determined by the extensive focus on specific aspects (e.g., partner selection and technologies).

A comprehensive theoretical model or empirically tested framework to support seamless interoperability in a CCENE and explain the complex relations between heterogeneous organizations is not yet available.

1.1. Aim and main research questions

The aim of the work pursued has been to advance the research in the area of interoperability in a CCENE, considering current challenges and general requirements towards seamless interoperability.

The main research questions that have guided this research work are:

(1) Which are the key directions to characterize and analyze interoperability in a CCENE?
(2) Which are the main requirements for interoperability in a CCENE?
(3) How can seamless interoperability be achieved?

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By attempting to answer these questions, a conceptual framework has been thought, aimed at attaining seamless interoperability in a CCENE. It follows a service-oriented approach and tackles the main views on interoperability: technical, knowledge/information, and business/economic. It has been constructed based on 27 general requirements for interoperability identified by analyzing existing approaches (e.g., industry-neutral and industry-specific initiatives, results of relevant R&D projects).

1.2. Related work/background

Several approaches (e.g., standards, reference models, architectures, frameworks, industry-neutral and industry-specific initiatives) have been developed. However, their focus is mainly on technical aspects related to inter-organizational communication.

Relevant European initiatives, frameworks and roadmaps to develop interoperability of enterprise applications and software are presented in [10], e.g., ATHENA (www.athena-ip.org), IDEAS (www.ideas-roadmap.net), INTEROP NOE (http://interop-noe.org) EU-funded projects. The authors advance three main research domains: enterprise modeling, architectures and platforms, and ontologies. However, the authors do not tackle business/economic interoperability aspects.

One European project, ECOLEAD, (www.ecolead.org) has directly addressed issues on CN performance. Preliminary results have been presented (e.g., [11]), with focus on social networks and the metrics proposed refer to "task level".

An agent-based approach to systems interoperability is described in [12]. Experiences in designing and integrating collaborative engineering environments supported by tools that enable cooperative work and intellectual capital sharing, based on an action research approach are introduced in [13]. An approach for an interoperable industrial networking architecture consisting of two fieldbus segments is proposed in [14]. A modeling framework for agile and interoperable virtual enterprises is presented in [15]. However, semantic and business/economic aspects are not addressed.

A number of areas that need further research in the context of a networked environment have been identified by researchers (e.g., [9,16]), including: the definition of reference models for CNs, the development of new applications, architectures and infrastructures to support CNs; knowledge-oriented collaboration; theoretical models. The issue of adopting a holistic approach on interoperability is of outmost importance to designers and managers (e.g., [17,18]). This article aims at addressing these challenges.

The rest of this article is organized as follows: the next section introduces the concept of seamless interoperability and presents a set of 27 general requirements for interoperability. Section 3 describes a conceptual framework that aims to achieve seamless interoperability in a CCENE. Then, a real implementation case from the footwear industry is illustrated, following the specifications of the proposed framework, emphasizing the advantages of this approach over previous initiatives in this sector. In Section 5, the proposed conceptual framework is compared with other three e-business frameworks. A mapping to the general requirements for interoperability is elaborated. The paper concludes with a section addressing the needs for further research.

2. Seamless interoperability in a collaborative–competitive economic networked environment

2.1. Collaborative networks: an overview

A CN represents a group of heterogeneous organizations with different yet symbiotic competences that combine their most suitable skills and resources for a determined period of time in order to achieve a certain goal. They use of ICTs to support their collaborative activities [3].

An outline of the most relevant theories and approaches which can support CN formal modeling and representation were identified and described in [4], emphasizing their strengths and weaknesses: graph theory, game theory, business processes alignment, Petri nets, Gaussian networks, transaction cost economics, social networks, micro-economics, decision theory, utility theory and monopolistic practices.

The term CNs is used in this article in a broad sense for other collaborative organizational forms with similar characteristics, such as virtual organizations (VOs), virtual enterprises (VEs) or extended enterprises. What differentiates a CN from other organizational forms with similar properties refers to: a CN (and its member organizations) aim at maximizing their payoffs; the existence of a collaboration agreement between CN member organizations; and the existence of a CCENE, where organizations exist and act.

While similar concepts defined to characterize the networked environment in which individual organizations and CNs collaborate, compete and act rely on the concept of *broker*, which intermediates offers and demands, such as: Digital Business Ecosystem (www.digital-ecosystem.org), collaborative–competitive economic environment (e.g., [4]), Market of Resources (e.g., [19]) or Virtual Enterprise Breeding Environment (e.g., [6]), the notion of CCENE (as proposed in this article) relies on the concept of *Business Enabler* (*BE*). The BE is an entity within the CCENE with the sole scope to ease inter-organizational collaborations. Only the terms collaborative–competitive economic environment, Market of Resources and CCENE emphasize the economic nature of the relationships of the individual organizational and CNs (e.g., by referring to payoffs). When a business opportunity is identified, the organizations join their resources to achieve a common objective, which is attained by setting-up and operating a CN. Different CNs may coexist simultaneously in a CCENE and an organization can belong to several CNs at the same time (e.g., [4]).

Although collaboration brings significant benefits to organizations, there is a relatively high failure rate among collaborative companies (e.g., [20]). According to [21], the number of corporate alliances increased with approximately 25% a year, and they account for nearly a third of many companies' revenue and value—yet the failure rate of alliances is about 60–70%. Main reasons for failure have been gathered in [20]: lack of commitment from one or more partners; failure to identify a common ground; unrealistic objectives of partners; failure to fulfill objectives and needs of partners; failure to focus on customer needs; focus on individual short-term benefits rather than on long-term collective benefits; unfair distribution of benefits due to ignorance of each other's competencies and contributions; the absence of an adequate operational system to manage the collaborative enterprise; the lack of reliable guides along the road to e-business transformation.

The reasons for failure, thus, are related to technical, information/knowledge and business/economic issues.

2.2. Seamless interoperability

2.2.1. Introduction

Interoperability refers to the use of ICTs to facilitate the coordination of work and information flow (e.g., [1]).

In this article, seamless interoperability refers to the use of computer-based tools to assure information exchange and the use of this meaningful information exchanged or shared between heterogeneous and geographically distributed organizations in a CCENE. The aim is to achieve value added by attaining a set of objectives, while the systems are added and/or removed without

requiring reconfiguration. Also, an organization, CN, or sub-CNs, decision to join, leave or remain in a CN or community is based on an economic analysis.

Towards seamless interoperability in a CCENE, main views on interoperability have been identified (e.g., technical, information/knowledge, business/ economic) which are detailed in the following sections. These directions have been also referred in two EU-funded projects: ATHENA and IDEAS.

2.2.2. Technical interoperability

Technical interoperability concerns technical issues related to e-communication, e.g., issues on linking applications and services addressing aspects related to [17]: interfaces; ICT platforms; information integration; exchange and accessibility; security, standards; services.

It addresses reference models, e.g., Supply-Chain Operations Reference model (SCOR, www.supply-chain.org), Workflow Reference model (www.wfmc.org); standards, e.g., cXML (www.cxml.org); architectures (e.g., model-driven, service-oriented, Web services, peer-to-peer, agent, grid, component-based, message-oriented architectures); frameworks (e.g., Zachman's Framework), industry-neutral (e.g., ebXML) and industry-specific initiatives (e.g., papiNet, RosettaNet, Chem e-standards), technologies and ICT platforms developed in order to support enterprise integration and interoperability. Web Services (www.w3.org/2002/ws) are aimed at providing a standard means of inter-operation between software applications. Simple Object Access Protocol (SOAP, www.w3.org/TR/soap), Universal Description Discovery and Integration (UDDI, www.oasis-open.org/committees/uddi-spec), Web Service Definition Language (WSDL, www.w3.org/TR/wsdl), and Business Process Execution Language (BPEL, http://docs.oasis-open.org/wsbpel) are the core Web Service specifications and are all instances of XML applications.

A survey of major standards on enterprise integration and engineering is presented in [22]. Challenges, trends and issues which should be addressed in order to support technological solutions for enterprise integration and interoperability have been described in [9] and [23]. Developments on architectures for enterprise interoperability are analyzed in [24]. A review of the most relevant approaches targeting technical interoperability in a CCENE is available in [1].

The following paragraphs focus on major industry-neutral initiatives, and relevant industry-specific approaches. Their main drawbacks and challenges have been analyzed in depth in [1].

ebXML (www.ebxml.org) is a modular set of specifications aimed at enabling e-business over the Internet for enterprises of all sizes in any geographical location. It comprises the following elements: messaging, registry/repository, business process specification schema, collaborative partner profile/agreement, and core components.

ebXML messaging specifications (ebMS) define a standard communication protocol for the reliable and secure exchange of messages. The ebMS uses the SOAP standard. The protocol assures a 'once-and-only-once' delivery of messages and their confidentiality, authentication and privacy while using the Internet as the communication media. The ebXML messages are XML-based and contain a payload part where any kind of data contents can be encapsulated (e.g., pdf, xml, text and binary), without size restrictions. The messages are transported over the Internet through SMTP or HTTP/HTTPS.

The collaborative partner profile/agreement specifications provide definitions of the documents that describe the commercial and technical capabilities of the e-business partners and the agreed interactions between them.

The *European Interoperability Framework* (EIF) [25] is aimed at supporting the pan-European delivery of e-government services to citizens and enterprises. It addresses information content and recommends technical policies and specifications to help connect public administration information systems across the EU. It considers three aspects of interoperability: technical, organizational and semantic.

papiNet (www.papinet.org) is an international paper and forest industry e-business initiative. Its aim is to enable information flow among parties engaged in buying, selling and distributing paper and forest products. The papiNet standard includes a common terminology and standard XML-based business documents for use in domestic and international electronic transactions. It is compatible with ebMS, even though it supports the FTP protocol.

RosettaNet (www.rosettanet.org) is a consortia that develops standards for the high-tech and electronics industry supply chain and supports their implementation and adoption. It consists of four main elements: multiple messaging service, which addresses XML-based messages exchange and B2B collaboration over horizontal message handling systems; Partner Interface Processes (PIPs) and PIP Directory; business and technical dictionaries, and RosettaNet Implementation Framework (RNIF). A PIP defines specific business processes between trading partners. RosettaNet's PIPs fit into seven clusters, which represent the backbone of the trading network. The RNIF is the packaging, routing and transport of all PIPs messages and business signals.

2.2.3. Information/knowledge interoperability

In this article, the notion of information/knowledge interoperability refers to the following aspects: information/knowledge representation and management, learning ability, rights to access information, knowledge sharing, aspects related to the adaptation and recombination of knowledge in a CN during its life-cycle.

Research in this area is relatively scarce. Relevant tools and approaches are listed below: the Web Ontology Language (OWL, www.w3.org/TR/owl-features), the Knowledge Interchange Format (www.ksl.stanford.edu/knowledge-sharing/kif), the Knowledge Sharing Effort (www.darpa.mil), knowledge engineering, Common KADS [26], ATHENA Enterprise Knowledge Specs [27].

Main collaboration knowledge sources have been presented in [16], e.g., experience of current and previous collaborations, knowledge of potential and actual partners, knowledge of collaboration practices in industrial sectors.

Semantic interoperability assures that the information exchanged by heterogeneous and geographically distributed organizations/systems is meaningful and that all the communicating parts interpret it in the same way (e.g., [1]). It provides a backbone for knowledge systematization, representation and sharing.

An overview of semantics and relevant approaches towards seamless semantic interoperability in a CCENE (e.g., standard-based approaches, semantic technologies, architectures development, business vocabularies and UN/CEFACT Modeling Methodology) is available in [1]. The authors also highlight main barriers against full semantic interoperability, such as: lack of standards, lack of an automatic way to map, align, integrate and merge ontologies, difficulties in identifying and solving ontology mismatches.

2.2.4. Business/economic interoperability

In the research work pursued, the notion of business/economic interoperability addresses interoperability issues between two or more systems from a business/economic perspective, as opposed to technical aspects. However, there might be applications, tools and technical methods to support business/economic interoperability aspects.

It refers to the ability of an organization, CN or sub-CN to join, leave or remain in a CN and to establish and remove inter-

organizational collaborations and relationships considering economic aspects.

Thus, business/economic interoperability comprises: the ability to collaborate across organizational boundaries and establish advantageous collaborations and flows (e.g., in terms of costs, payoffs, time and level of quality), which are seamlessly integrated in a way that organizations' boundaries are imperceptible from the inter-organizational collaborations' perspective; the ability to set-up, change and remove inter-organizational collaborations in a profitable way (e.g., considering the report between costs and payoffs); organization and CNs performance assessment; an organization, CN or sub-CNs decision to Join, Leave or Remain in

Table 1
General requirements for seamless interoperability in a CCENE.

Requirement	Name	Description
(1) General requirements addressing organization's Collaboration Profile (CP) Description and Publication	Organization's CP Description	The information representing the description of an organization's CP should follow a predefined format (e.g., general information, technical details and business details).
	Organization's CP Publication	An organization should be able to publish its CP.
(2) General requirements concerning potential business partner/opportunity Identification	Browse Information	Specifications concerning an organization's ability to access and browse the information stored in the centralized repository, such as: the information published by other organizations (e.g., other organization's CP).
(3) General requirements addressing Collaboration		
(3.1) Messaging	Communication	Different geographically distributed organizations should be able to communicate by exchanging messages.
	Message format	Two communicating organizations/systems should use a common format for the messages exchanged while performing e-business.
	Business documents format	Two organizations exchanging messages should use a common format for the business documents encapsulated in the messages exchanged by two communicating systems/organizations while performing e-business.
	Connection to Internet	The messaging specification should have an alignment with the principles of communicating/exchanging messages over the Internet.
	Security	Security aspects of e-communication should be addressed (e.g., confidentiality, authentication, non-repudiation).
(3.2.) General requirements for Collaboration concerning Inter-Organizational Collaborative Activities (IOCAs)	Definition and Specification of the IOCAs	All inter-organizational collaborative activities should be defined and specified.
	Business documents for a IOCA	All business documents involved in each inter-organizational collaborative activity should be specified.
	Business documents choreography	The sequence in which the business documents are exchanged in each inter-organizational collaborative activity should be specified.
(3.3) General requirements for Collaboration concerning Negotiation and Agreements	Negotiation	To provide organizations with specifications to negotiate.
	Agreement	To provide organizations with specifications to define and elaborate a collaboration agreement (CA).
(3.4) Semantics	Semantics of the information exchanged	The information exchanged (e.g., messages, business documents) is meaningful and has the same meaning for the communicating systems/organizations (e.g., the exchanged information is interpreted in the same way).
(4) General requirements addressing Management aspects		
(4.1) Information Management	Management of the stored information	All stored information (e.g., concerning CPs, templates of business documents) should be managed, for example, to avoid duplication of data, to assure the stored information has a valid format, to support the archiving of the CA (e.g., in order to provide the possibility to reconstruct the semantic intent of a CA several years after its creation).
	Information Availability	Accurate and consistent information (e.g., CPs, business documents templates) should always be provided to organizations.
(4.2) Policy	Compliance with Legislation and National/International Recommendations	The organizations should perform e-business taking into account the national and/or international legislation, the specifications and recommendations of different national and international bodies, e.g., concerning product labeling, recommendations of UN/CEFACT and standardization institutions, such as NIST (www.nist.gov), attempting to harmonize the specifications of a framework and the information format with different approaches and initiatives, in order to ensure conformance with available standards or even a certain level of compatibility with existing specifications and practices.
(4.3) CN Management	Conflict Solving	To address aspects related to solving potential conflicts which may appear between e-business partners, e.g., concerning non-repudiation.
	Rights and Obligations	The rights and obligations of an organization in a CCENE and CN should be clearly defined and made available (e.g., the conditions in which an organization may erase its CP and leave a community, to verify if the CA is respected—for example, two organizations should be able to exchange only the business documents they have agreed to exchange), to define access rights, for example, concerning total or restricted access to certain information.
	Roles/Tasks Fulfillment	To provide specifications to monitor the organization's roles and tasks fulfillment (e.g., according to the CA).
	Learning	To address aspects related to the learning ability of a CN and/or its member organizations.

Table 1 (*Continued*)

Requirement	Name	Description
(4.4) Dissemination	Accessibility	Accurate, easy, free access to specifications for all users, e.g., in order to eliminate entry barriers of potential organizations.
	Dissemination of the specifications	To address aspects related to the dissemination of the specifications of a certain framework and implementation initiatives (e.g., tools, ICT platforms) which have followed these specifications, the advantages to be attained by organizations.
(5) General requirements addressing Performance Assessment	Performance Assessment	To provide specifications for the elaboration of a performance assessment analysis for organizations and CNs (e.g., to support a Join/Leave/Remain decision).
(6) General requirements addressing Non-Functional aspects/properties	Generality	To have a relatively high degree of generality, e.g., considering the possibility to customize it to a certain industry, to assure the technical evolution (e.g., separating data transport from business aspects).
	Comprehensibility	The specifications should be clear, rigorous, and easily understood, e.g., concerning the time and work necessary to understand its specifications.
	Versioning	To consider versioning support (e.g., of business documents, CAs) in order to support and facilitate the reconstruction of the semantic meaning of a transaction, in accordance with the underlying transaction format that is used.

a CN or community, considering economic aspects (e.g., cost and payoff); elements of coordination theory (as described in [28]). Business interoperability is also related to the CNs definition of goals and strategy and the alignment of individual goals and strategies with those of the CN.

A review of existing studies analyzing the economics of CNs is available in [4]. The authors also propose a three dimensional model to support organizations and CNs performance assessment, and a Join/Leave/Remain decision. The three proposed axes are cost, payoff and agility.

2.2.5. General requirements

The extensive research on interoperability enabled the identification and definition of a set of 27 general requirements for seamless interoperability in a CCENE, presented in Table 1. They have been grouped in six core categories: (1) description and publication; (2) potential business partner/opportunity identification; (3) collaboration, which includes: messaging; inter-organizational collaboration activities; negotiation and agreement; semantics; (4) management, which comprises: information management; policy; CN management; dissemination; (5) performance assessment; (6) non-functional aspects.

These 27 general interoperability requirements identified and the gap analysis presented in [1] represented the input for the elaboration of a conceptual framework towards seamless interoperability in a CCENE.

3. Collaborative interoperability framework

3.1. Introduction

The conceptual framework thought, named Collaboration Interoperability Framework (CIbFw), aims at attaining seamless interoperability in a CCENE. It comprises six elements, as follows: (1) a messaging service, responsible for the e-communication among organizations; (2) a Collaboration Profile/Agreement Definition and Management (CP/ADM) service; (3) five clusters of collaborative business activities; (4) a centralized repository; (5) a set of business documents and a set of contracting documents; (6) a performance assessment service.

The design of the infrastructure has been made in accordance with the principles of the service-oriented architecture (SOA) [29] in order to obtain a good organization of the infrastructure and increase its scalability.

The CIbFw involves three main types of entities:

(1) *Organizations* (e.g., enterprises), which aim at maximizing their payoffs (e.g., tangible and intangible payoffs). Table 2 presents the main types of actors identified in an organization.
(2) *CNs* represent a group of organizations within the CCENE, which are conducting e-business in order to achieve a specific goal agreed by all its member organizations. A CN is set up and starts to operate after its members have agreed on a

Table 2
Main types of actors in an organization.

No. Crt.	Name	Description
1.	Manager	This actor is an employee of an organization and holds a top position; (s)he has decision power and gives specific orders to other actors (e.g., Employee, SystemManager, ProfileManager, RequestingAgreementManager and RespondingAgreementManager) and provides them with the necessary information to execute these orders.
2.	Employee[a]	This actor is a person who can belong to any department of an organization and creates, sends, processes and/or receives a business document.
3.	SystemManager[a]	This actor is an employee of an organization responsible for the technical management of the organization's system.
4.	ProfileManager[a]	This actor is an employee of an organization responsible for all the tasks related to the management of the organization's collaboration profile, and performs activities related to the organization's performance assessment.
5.	RequestingAgreementManager[a]	This actor is an employee of an organization who makes a first business proposal to one or a set of organizations (previously selected by the Manager of the organization) by uploading a first valid draft of a Collaboration Agreement (CA) document to the centralized repository. This actor has the ability to manipulate (e.g., download, upload) CA documents. (S)He uploads the final CA document.
6.	RespondingAgreementManager[a]	This actor is an employee of an organization who has received a notification from the BE's system saying that an invitation to perform e-business exists (in the form of a first valid draft of a CA document uploaded in the centralized repository by a RequestingAgreementManager of another organization in the CCENE). This actor has the ability to manipulate (e.g., download, upload) CA documents.

[a] This actor does not have any decision power. (S)He just executes the orders received from the Manager of the organization.

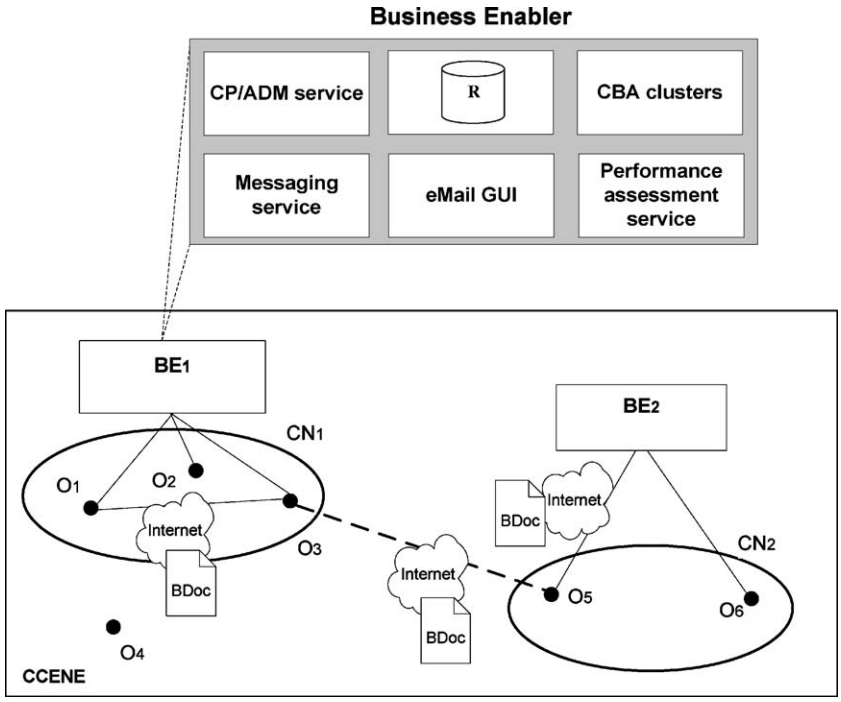

Fig. 1. Pictorial representation of the Business Enabler concept in an industrial CCENE.

collaboration agreement (CA), which has been signed by the Business Enabler's system.

(3) *Business Enabler (BE)* is an entity within the CCENE. Its main responsibility is to ease inter-organizations' partnerships and agreements setting and management, supporting the CNs and their member organizations to achieve their goals. Several BE's may coexist in a CCENE (e.g., one BE for each industry sector) and they enable intra- and cross-industry communication. The main responsibilities of a BE may include (but are not limited to): solving potential conflicts, e.g., related to message repudiation; dissemination of the initiative; managing a Portal where public information is available, e.g., related to the services supported by the BE's system.

The BE's system may perform the following tasks: store information in the centralized repository (e.g., organization's collaboration profile—CP); manage the centralized repository; provide different services to organizations and CNs (e.g., messaging, CP/ADM and performance assessments); provide specifications for inter-organizational collaborations; provide software (e.g., to be installed to organizations, in order to enable electronic communication to the ICT platform); check the validity of all forms submitted (e.g., CP forms submitted); sign the final CA document; provide templates for the CA document and business documents; provide preliminary information (e.g., the benefits and responsibilities of an organization in a community); send notifications (e.g., to the organizations involved in the negotiation of a CA document each time a new version is uploaded to the centralized repository). The BE's system makes available *software-as-a-service* to the organizations which have submitted their CP.

Fig. 1 portrays the concepts introduced. Six organizations (named from O_1 to O_6), two CNs (CN_1 and CN_2), and two BE's (BE_1 and BE_2 respectively, which could be, for example, BE's for two different industries) have been represented. Two organizations (from the same industry or from different industries) may communicate over the Internet, by exchanging messages (which encapsulate business documents), in two ways (as agreed in the CA document): *through the BE(s)' systems*, by making use of the messaging service or e-mail service (eMail GUI); or *on a peer-to-peer basis*, in order to increase their communication privacy.

Some organizations in the CCENE (e.g., O_4) may not be involved in any CN, but they may provide different services to other organizations (e.g., outsourcing).

The UML representation of the BE's system functionality is illustrated in Fig. 2. The transactions between all actors and the BE's system are illustrated.

Table 3 contains a brief description of the use case illustrated in Fig. 2, highlighting their results and the main actor(s) involved. The most relevant use cases are detailed in the following sections.

CIbFw's inter-organizational interactions follow the ebXML's scenario. However, the approach is different, since, unlike ebXML framework, the CIbFw relies on the concept of BE and promotes two types of communication: mediated by the BE, or peer-to-peer.

Fig. 3 illustrates the interaction diagram of the CIbFw scenario for two organizations. Organization A adheres to the community, while Organization B is already a member of the community. The two organizations negotiate and, after setting a CA, they start to perform e-business by making use of the messaging service provided by the BE's system. Seven main steps may be identified: (1) request business details; (2) build local system implementation; (3) Organization A submits its CP; (4) query on organization's A CP; (5) Organization B makes a first business proposal to Organization A by uploading to the centralized repository a first valid draft of a CA document; (6) Organizations A and B negotiate; (7) Organizations A and B perform e-business.

3.2. Messaging service

The CIbFw promotes two types of e-communication between e-business partners: by making use of the messaging or e-mail service provided by the BE's system, or directly, on a peer-to-peer basis.

The BE's system is responsible for the secure and reliable transmission of messages among organizations (e.g., finding an alternative communication way when e-communication fails). Thus, the organizations do not have to set an agreement concerning

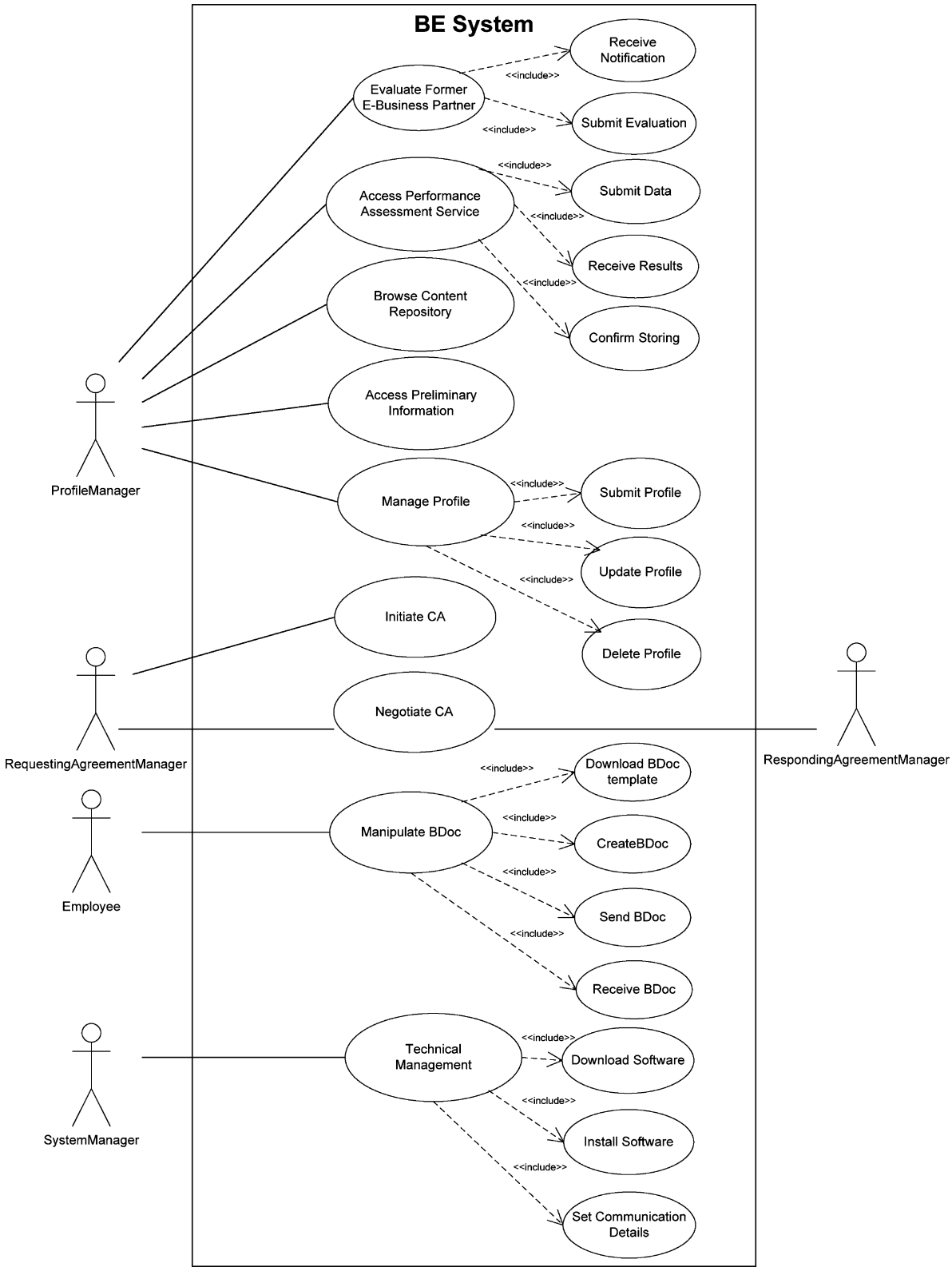

Fig. 2. Actors and the BE's system (UML).

technical communication details (e.g., the communication protocol to be used), which is time and cost consuming, especially when an organization conducts e-business with a big number of different organizations. However, some organizations may decide to communicate on a peer-to-peer basis, in order to increase their privacy. This choice has to be specified in the CA document (Section 3.4.2.2).

It supports trading partners in exchanging messages over the Internet, which encapsulate business documents. Additional elements (e.g., Application Program Interfaces—APIs) may also be present. For example, external applications, such as ERP solutions, may use the API to send/receive business documents from external trading partners.

Table 3
Overview of the use cases.

No. Crt.	Use case	Primary actor(s)	Description	Result(s)
1.	Technical Management	SystemManager	In order to perform e-business through the messaging service provided by the BE's system, an organization needs to set its communication details (e.g., download and install specific software).	The communication details of the organization have been set. The organization is ready to connect to the ICT platform.
2.	Access Preliminary Information	ProfileManager	In order to support the Manager's decision to adhere or not to a community, the preliminary information provided by the BE on its Portal is consulted.	The ProfileManager consults the preliminary information provided by the BE, and communicates it to the Manager of the organization.
3.	Manage Profile	ProfileManager	This use case refers to the management of an organization's CP.	The organization's CP is submitted, updated or deleted.
4.	Browse Content Repository	ProfileManager	In order to select potential business partners and perform e-business, the ProfileManager browses the information stored in the centralized repository.	The ProfileManager browses the information stored in the centralized repository, selects the information requested by the Manager (e.g., organizations that have a certain CP), and communicates it to the Manager of the organization.
5.	Access Performance Assessment Service	ProfileManager	Following the orders received from the Manager of the organization, the ProfileManager accesses the performance assessment service provided by the BE's system in order to elaborate a performance analysis.	The results obtained through the access to the performance assessment service are displayed by the BE's system. A Performance document is created or updated if a confirmation from the ProfileManager is received.
6.	Evaluate Former E-Business Partner	ProfileManager	Following the orders received from the Manager of an organization, the ProfileManager submits the evaluation of a former e-business partner.	The ProfileManager submits the evaluation of a former e-business partner after receiving a notification from the BE's system. The BE's system updates the *performance_history* section of the CP document with this information, increments the version of the CP document, and sends a notification to the organization being evaluated that its CP has been updated with the evaluation received from its former e-business partner.
7.	Initiate CA	RequestingAgreementManager	This use case describes the steps performed by the RequestingAgreementManager to initiate a CA.	The RequestingAgreementManager invites an organization to participate in a business partnership by uploading a first draft of a CA document with the *status* field set to '*proposed*'. The CA document is checked by a software program executed by the BE's system, and if it has a valid format, a notification is sent to the RespondingAgreementManager.
8.	Negotiate CA	RequestingAgreementManager and RespondingAgreementManager	This use case describes the negotiation process between the RequestingAgreementManager and RespondingAgreementManager towards a final CA document.	The RequestingAgreementManager and the RespondingAgreementManager negotiate by uploading different versions of the CA document to the centralized repository in order to reach an agreement—that is a final CA document with the *status* field of the CA document set to '*agreed*'. After setting a final CA document: both actors have access to each other's bank information. Both actors may download a copy of the final CA document, signed by the BE's system, which acts as a Notary and sets the *status* field of the CA document to '*signed*'. Now, the organizations can start performing e-business.
9.	Manipulate Business Documents	Employee	In order to perform e-business, an organization creates, sends and receives business documents.	The Employee manipulates business documents (e.g., sends, receives, creates a business document, downloads templates of business documents)

The business documents exchanged between e-business partners are embedded in electronic messages. They are, in fact, the payload of the exchanged messages. The structure of a message follows ebXML specifications. The communication/transport protocol envelope and the message service envelope concern the transport protocols and the message protocols, respectively. The envelope consists of a *header*, which contains information about the nature of the message to be delivered, information necessary to route the message; a *body*, which includes the precise definition of the data elements in the message; a *payload*, which represents the actual e-business document transmitted by an organization (acting as a *sender*) to another organization (acting as a *receiver*). A payload encapsulates one business document and, optionally, a set of supporting electronic documents (e.g., a CAD file containing the characterization of a product). A signature element may also be packaged to the payload.

The elements of the messaging service provided by the BE's system are detailed in Section 4.

The messaging service alone is not enough to achieve broad scale interoperability across heterogeneous and geographically distributed organizations. Thus, additional elements have been thought, which are described in the following paragraphs.

3.3. Collaboration profile/agreement definition and management service

The CP/ADM service aims at supporting the definition and management of an organization's collaboration profile (CP) and agreements. This element is addressed in steps 3, 4, 5, 6 and 7 of the interaction model illustrated in Fig. 3.

3.3.1. The collaboration profile

After deciding to adhere to a specific community, the organization's CP (e.g., name, contact details, bank details and supported business documents) is defined and submitted to the

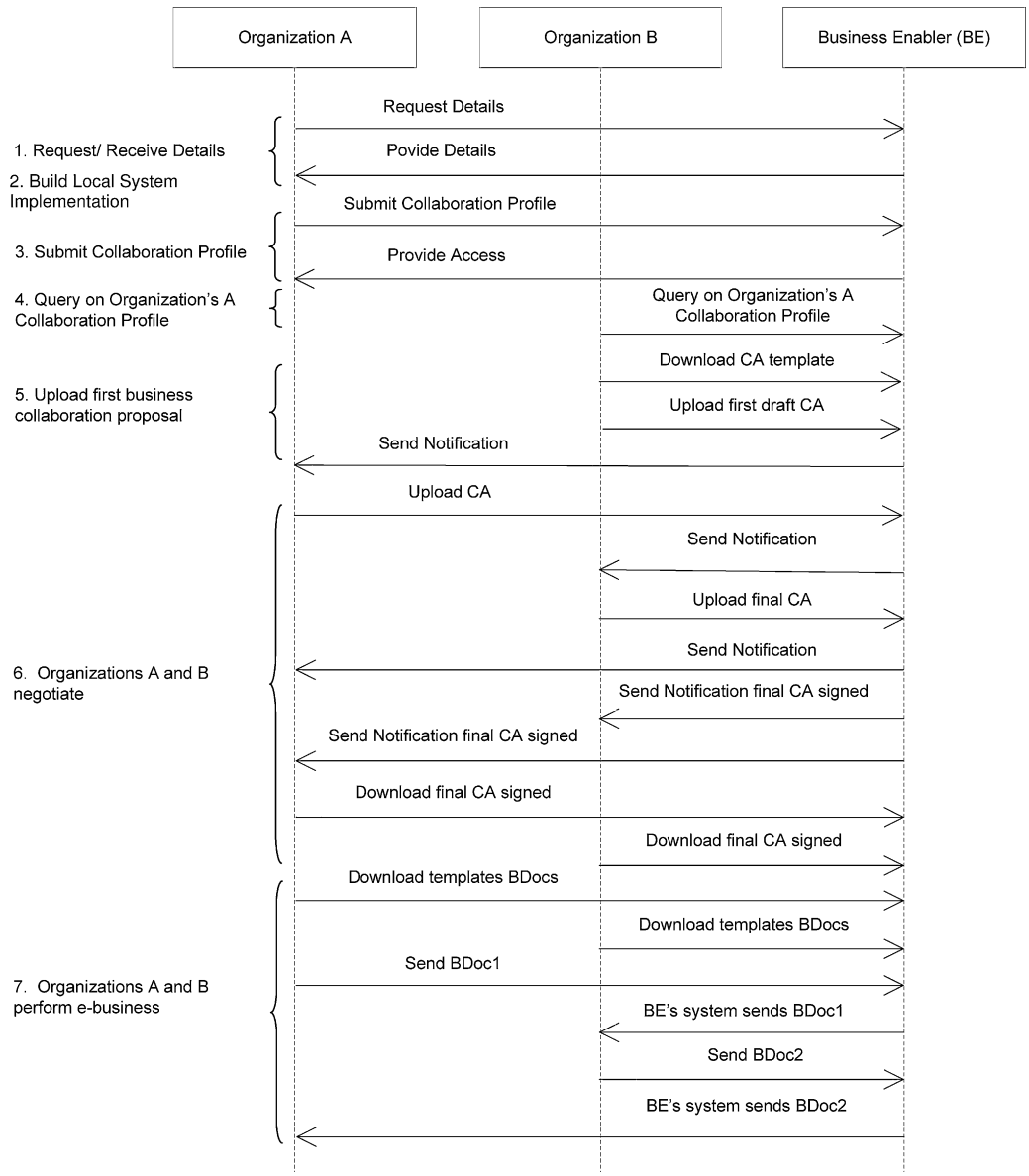

Fig. 3. The ClbFws interaction diagram.

centralized repository. The ProfileManager actor fills in and submits a form made available by the BE's system. In fact, the ProfileManager actor is responsible, at the organization's level, for all aspects related to an organization's CP (e.g., submit, delete, update the organization's CP). The information submitted is checked by the BE's system, which saves it in the centralized repository as a CP document, and assigns it a unique identifier (*cp_id*). The content of a CP document is detailed in Section 3.4.2.1.

All CPs stored in the centralized repository may be accessed by all the members of the community, which are searching for potential e-business partners.

Table 4 illustrates a formal description of 'Manage Profile' use case.

3.3.2. The collaboration agreement

Before two organizations actually start to perform e-business, they need to define a CA, which corresponds to an intersection of their CPs and includes additional results on negotiating variable parameters (e.g., items or products to be delivered, minimum and maximum response times).

The CA between two organizations is stored by the BE's system in the centralized repository as a CA document, to which it assigns a unique identifier (*ca_id*). The content of a CA document is detailed in Section 3.4.2.2.

The RequestingAgreementManager initiates the CA definition. (S)He downloads the CA template form the centralized repository, fills it in and uploads it to the centralized repository (with the *status* field set to 'proposed'). Then, the BE's system sends a notification to the RespondingAgreementManager that a first business proposal exists in the form of an initial CA document. The RequestingAgreementManager and RespondingAgreementManager negotiate by uploading intermediate CA documents to the centralized repository. Each time a new version of the CA document has been uploaded, the BE's system sends a notification to the actors involved. The final CA document is set by the RequestingAgreementManager, who uploads it with the *status* field set to 'agreed'. The BE's system signs it, acting as a Notary, by setting the *status* field of the CA document to 'signed', and notifies the actors involved that they may download a copy of the final CA document signed.

Table 4
Formal description 'Manage Profile' use case.

Name	Manage Profile		
Primary Actor	ProfileManager		
Secondary Actor	Manager		
Description	This use case refers to the management of an organization's CP.		
Pre-Condition	The Manager decided that the organization should adhere to the community.		
Relationships	Extends. . ..		Includes. . .. 'Submit Profile' use case 'Update Profile' use case 'Delete Profile' use case
Basic Flow	Actor action	System response	
a. Submit Profile		1a. The BE's system makes available a CP form[a].	
	2a. The ProfileManager fills in all the fields of the CP form with the data received from the Manager.		
	3a. The ProfileManager submits the form by entering the "*Submit Collaboration Profile*" button.		
		4a. The BE's system executes a software program[b] that checks the validity of the data submitted.	
		5a. The BE's system generates a cp_id.	
		6a. The BE's system stores the organization's CP as a CP document.	
b. Update Profile		1b. The BE's system provides a Web page where the ProfileManager introduces the organization's identifier (ID).	
	2b. The ProfileManager introduces the organization's ID.		
		3b. The BE's system executes a software program[c] to compare the ID introduced with the IDs stored in the centralized repository.	
		4b. The BE's system retrieves the content of the CP document and displays it as a CP form.	
	5b. The ProfileManager updates certain fields of the CP document/CP form.		
	6b. The ProfileManager submits the updated document/form.		
		7b. The BE's system executes a software program[d] that checks the format of the submitted data.	
		8b. The BE's system saves the updated CP and increments the CP document's version.	
c. Delete Profile		1c. The BE's system provides a Web page where the ProfileManager introduces the organization's ID.	
	2c. The ProfileManager introduces the organization's ID.		
		3c. The BE's system executes a software program[e] to compare the ID introduced with the IDs stored in the centralized repository.	
	4c. The ProfileManager clicks the '*Delete Collaboration Profile*' button.		
		5c. The BE system executes a software program[f] that checks the possibility of the organization to delete its CP (e.g., all the CAs in which it has been involved have ended).	
		6c. The BE's system stores the organization's cp_id in a separate file.	
		7c. The BE's system deletes the organization's CP (that is the CP document).	
		8c. The BE's system updates the access rights.	
Priority	*High*	Medium	Low

[a] The information in the CP form refers to general information, business details, and technical details.
[b] This software program is stored in the centralized repository and may be executed only by the BE's system. Its purpose is to check if the information submitted by the ProfileManager has the correct data type (e.g., by comparing them with a set of predefined data types, which are stored in the centralized repository).
[c] This software program is stored in the centralized repository and may be executed only by the BE's system. Its purpose is to compare the ID introduced by the ProfileManager with the IDs of the organizations in the community, which are stored in the centralized repository.
[d] Idem b.
[e] Idem c.
[f] This software program is stored in the centralized repository and may be executed only by the BE's system. Its purpose is to check if the organization may delete its CP based on a set of predefined conditions which are stored in the centralized repository.

3.4. Business documents and contracting documents

The proposed framework is document-oriented. In fact, it lies on the simple and natural idea of exchanging documents over the Internet. Different business partners use business documents to perform e-business. An organization's CP and their negotiated CAs are also specified as documents.

CIbFw involves two types of documents: *business documents* exchanged between the organizations performing e-business which support the dynamic and operational daily business, and *contracting documents* that are static and refer to collaboration profiles, business agreements and performance statements.

3.4.1. Business documents

A business document is characterized by *content*, which represents the transmitted information; *composition*, illustrating the way the business documents' content are arranged, and *choreography*, representing the sequence in which the business documents are exchanged.

The business documents are recommended to be built with semantics in order to assure intra- and cross-industry semantic interoperability. In this sense, a standardized set of messages may be used, e.g., the XML Common Business Library (www.xcbl.org), or the library of schemas provided by the Universal Business Language (www.oasis-open.org/committees/ubl). For the foot-

wear and textile industries, essential business documents have been identified, defined by SHOENET and TexWeave initiatives.

To assemble a business document, its content and composition are determined. Then, the schema for the business document is defined by assembling these elements. A business document encapsulates a *BusinessHeader* element, which represents the header of the business document, and a *BusinessDocumentDetails* element, which contains the actual e-document.

The *header* of a business document may comprise the following elements: *SenderInformation* refers to the information about the sender of a business document (e.g., *SenderId*, which represents the identifier of the organization, *SenderInfo*, which contains information on the organization, such as name and contact details); *ReceiverInformation* refers to the information about the receiver of a business document; *DocumentNumber* represents an identifier of the business document; *DocumentName* represents the name of the business document; *DocumentDate* represents the issuing date of a business document; *SpecificInformation* contains specific information (e.g., *PaymentInformation* contains information related to the method of payment; *RequestedDeliveryDate* indicates the required date to deliver the products); *Comment* represents textual information that the organization sending or receiving a business document wishes to include.

3.4.2. Contracting documents

Three main types of contracting documents involved in the CIbFw are described in the following paragraphs: CP, CA and performance documents.

The CP document is a document which must be specified by an organization when it intends to adhere to the infrastructure. The submission of a new CP allows all organizations which have already adhered to the infrastructure to access the new CP and set up partnerships with the respective organization.

3.4.2.1. Collaboration profile document. A CP document, which represents an organization's CP, describes an organization's capabilities to engage in collaborative activities with other organizations. It is created automatically by the BE's system when the ProfileManager submits the organization's CP.

It may contain the following elements:

- *cp_id* represents a unique identifier associated automatically by the BE's system when the CP document is created;
- *general_information* contains general information on the organization, e.g., name, contact details and bank details;[2]
- *business_details* contains information regarding the business capabilities of an organization, e.g., the business documents the organization is capable to send and receive;
- *technical_details*[3] refers to the information related to the exchange of business documents, sender and receiver binding information, transport information, such as: transport protocol, transport security protocol, encryption algorithm, security details;
- *performancne_history* contains the results of the evaluations made by former e-business partners.[4] The information stored in this field may not be changed by the ProfileManager of the organization, and is automatically updated by the BE's system when a new evaluation of the organization has been submitted by a former e-business partner;
- *comment* represents additional textual information that the Manager of an organization desires to include.

Unlike ebXML, where each enterprise has more than one CP (e.g., a CP for each of the supported roles), the CIbFw approach encourages the definition of only one CP for an organization.

3.4.2.2. Collaboration agreement document. A CA document has the role of a formal business contract between e-business partners. It specifies the agreement between two organizations in order to perform e-business, e.g., the business documents to be exchanged and their sequence.

An overview of the structure of a CA document is listed below:

- *ca_id* represents a unique identifier assigned by the BE's system to a CA document when a first valid draft is uploaded to the centralized repository by the RequestingAgreementManager;
- *version* represents the version of the CA document, which is automatically incremented by the BE's system each time a new draft of the same CA document is uploaded to the centralized repository;
- *status*, e.g., proposed, agreed and signed;
- *general information* on the two organizations, e.g., name, contact details and bank details;
- *business details*, e.g., the business documents to be exchanged;
- *technical details*;[5]
- *comment* represents the textual information contained in the *comment* filed of the CP documents of the two organizations;
- *signature*, e.g., when the BE's system acts as a Notary and signs the final CA document.

3.4.2.3. Performance document. The Performance document[6] may contain the following information:

- *performance_id* is a unique identifier assigned by the BE's system when the ProfileManager confirms the storing of the information related to the performance assessment;
- *time* refers to the date and time the document has been created or updated;
- *costs* represents information related to the costs of an organization (e.g., estimated costs to join a CN);
- *payoffs* represents information related to the payoffs of an organization (e.g., expected payoffs by the participation in a CN);
- *other information* is relevant to elaborate a performance assessment, e.g., estimated inflation rate;
- *performance assessment results* refers to the results displayed by the BE's system which are obtained after the execution of a performance assessment analysis.

3.5. Inter-organizational collaborative business activities

A set of five operational clusters of Collaborative Business Activities (CBAs) has been specified to cover all the inter-organizational interactions in a CCENE. These operational clusters may be depicted in sections, as follows:

(1) *Order Management* enables full order management-related activities, e.g., from price and delivery quotation activities, to order initiation, change and cancellation, invoicing and payment. It contains the following sections: *(1.1) Pre-Order Management*, which addresses pre-order activities; *(1.2.) Order*

[2] The bank details are visible only to the business partners with whom the organization has already made a CA.

[3] The technical details are not visible to the organizations searching for a potential business partner in the centralized repository. This information is relevant only when the organizations communicate on a peer-to-peer basis.

[4] Details on the evaluation performed by a former e-business partner are available in Section 3.7.1.

[5] Unlike ebXML, according to the CIbFw, technical details are included in the CA document only if the organizations decide to communicate on peer-to-peer basis.

[6] Details on the creation of this document are available in Section 3.7.

Initiation, Change and Cancellation addresses activities related to the generation of an order and the requests to cancel or change an order; *(1.3) Order Status* focuses on the activities related to the status of an order; *(1.4) Delivery Notification* addresses activities related to the notification of delivery or reception of ordered items or products.

(2) *Product Design* aims at enabling the exchange of information related to product design activities. It comprises one section: *(2.1) Product Design Information Transfer* enables the communication related to the product design (e.g., test design information);

(3) *Marketing and Commercialization* aims at enabling communication of marketing information, including campaign plans, lead information and design registration. It comprises three sections: *(3.1) Sharing Information on Sales*, which refers to sharing the information related to sales; *(3.2) Management of Marketing Campaigns*, which enables communication of information related to marketing campaigns; *(3.3) Marketing Programs*, which supports the creation and use of marketing programs and the distribution of pricing incentives.

(4) *Product/Item Availability Management* aims at enabling the communication of the information concerning the availability of a certain product and/or item. It comprises six sections: *(4.1) Collaborative Forecasting*, which enables the standardization of collaborative order and sales forecasting between e-business partners; *(4.2) Product/Item Allocation*, which supports an organization in informing its business partners on product/item allocation (e.g., considering the demand forecast); *(4.3) Product/Item Availability Reporting*, which supports an organization to provide daily reports to its e-business partners, e.g., enabling an organization to send discrepancy reports; *(4.4) Replenishment*, which facilitates organizations in performing replenishments; *(4.5) Sales Reporting*, which enables organizations to provide periodic sales reports to product/item providers and discrepancy reports; *(4.6) Price Protection*, which enables organizations to announce and acknowledge price changes, process payments or credits resulting from changes.

(5) *Post-Sale Support* aims at enabling organizations to communicate information related to activities on post-sale technical support services or service warranty. It comprises three sections: *(5.1) Warranty and Support Registration*, which enables the registration of warranty and post-sale technical support; *(5.2) Upgrade and Auditing*, which enables activities related to upgrading, maintenance and auditing; *(5.3) Service and Support Management*, which focuses on the management of post-sale service and technical support.

The complete description of these five clusters is stored in the centralized repository.[7]

RosettaNet provides complete specifications for the PIPs defined, which are similar to the CBAs presented in this section. However, RosettaNet's specifications are tailored to the specificities of the electronics and high-tech industry. ebXML provides general specifications for inter-organizational collaborations within ebBPSS.

However, the main differences of CIbFw's CBAs, RosettaNet's PIPs and ebBPSS specifications concerns the level of generality in the descriptions of the inter-organizational collaborations.

This element of the framework is referred in steps 3, 4, 6 and 7 of the CIbFw interaction model presented in Section 3.1.

3.6. Centralized repository

The BE's system is responsible for the management of the centralized repository. It provides a stable store where information is made persistent. Such information is used to facilitate e-business partnerships and transactions.

The content of the repository refers to: templates (e.g., of business documents and CA documents), contracting documents (e.g., CP, CA and performance documents); specifications of the five CBAs and their sections; software components; other supporting information, e.g., schemas. Aspects related to security, e.g., data integrity, source integrity, authentication and access control are addressed by the BE's system.

An organization has access to the centralized repository through the following actors (Table 2), that access it through the interfaces provided by the BE's system: ProfileManager (e.g., when s/he submits, uploads or deletes the organization's CP), RequestingAgreementManager and RespondingAgreementManager (e.g., when they upload and download CA documents), SystemManager (e.g., when downloading software), and Employee (e.g., when downloading templates of business documents).

This element is referred in all the steps of the interaction model presented in Section 3.1.

3.7. Evaluation and performance assessment

3.7.1. Evaluation of former e-business partner

After a CA ends (e.g., because its validity ends or the number of exchanged business documents has expired), the BE's system sends a notification to the organizations involved in the CA to evaluate their former e-business partner. The BE's system provides an evaluation form and the ProfileManager is able to fill it in based on the information received from the Manager of the organization and submit it.

The evaluation form displayed by the BE's system has the following fields: identifier of the evaluated organization (e.g., cp_id), identifier of the organization performing the evaluation; evaluation score,[8] which characterizes the overall performance of the former e-business partner (e.g., fulfillment of tasks considering the deadlines); evaluation time; and evaluation date.

After receiving the evaluation of an organization submitted by the ProfileManager, the BE's system stores this information in the field *performance_history* of the CP document of the evaluated organization. Each time a new evaluation is submitted for an organization, its CP is updated (and its version is incremented), and the BE's system sends a notification to the organization (informing the organization that its former e-business partner has submitted an evaluation). The data contained in this field may be viewed by all the organizations in the community, and cannot be modified by any actor.

3.7.2. Service specifications

The performance assessment service aims to provide support for managers in a Join/Leave/Remain decision (e.g., a decision to join or not a community/CCENE or CN). This service may be accessed by the ProfileManager of an organization. To elaborate a performance assessment analysis, the Manager should provide accurate information to the ProfileManager (e.g., concerning estimated costs, expected payoffs and expected fluctuations of the inflation rate). The results obtained will be transmitted to the Manager of the organization. Two distinct situations have been considered: the ProfileManager of an organization which is not member of the community/CCENE accesses the performance assessment service (e.g., to support the Manager's decision to join or not a community), and the organization is member of the community/CCENE and the organization's CP is already stored in

[7] A more detailed description of the CBA clusters is available in [30].

[8] The evaluation score is a number on a 1–10 scale, where 10 denotes excellence.

Table 5
Formal description 'Access Performance Assessment Service' use case (for an organization member of the community).

Name	Access Performance Assessment Service		
Primary Actor	ProfileManager		
Secondary Actor	Manager		
Description	Following the orders received from the Manager, the ProfileManager accesses the performance assessment service provided by the BE's system in order to elaborate a performance analysis.		
Pre-Condition	The Manager collects accurate information and provides it to the ProfileManager.		
Relationships	Extends. . ..		Includes. . .. 'Submit data' 'Receive results' 'Confirm storing'
Basic Flow	Actor action	System response[a]	
a. Submit Data		1a. The BE's system displays a Web page where the ProfileManager may introduce the organization's identifier (ID).	
	2a. The ProfileManager introduces the organization's ID (e.g., cp_id) and presses '*Enter*' key.		
		3a. The BE's system executes a software program[b] to compare the organization's identifier introduced with the ones stored in the centralized repository. 4a. The BE's system retrieves the content of the Performance document stored in the centralized repository. 5a. The content of the Performance document is displayed as a form. The content of certain fields (e.g., concerning estimated costs and expected payoffs) may be modified by the ProfileManager.	
	6a. The ProfileManager fills in the form to elaborate a performance assessment. 7a. The ProfileManager submits the form by clicking the '*Submit*' button.		
b. Receive Results		1b. The BE's system executes a software program[c] that checks the correctness of the data type for the information submitted by the ProfileManager. 2b. The BE's system executes a software program[d] that selects the indicators which may be calculated considering the data introduced, and calculates these indicators. 3b. The BE's system displays the results of the performance assessment.	
	4b. The ProfileManager receives the results of the performance assessment.		
c. Confirm Storing	1c. The ProfileManager confirms that the data introduced and displayed may be stored by clicking the '*Confirm Storing*' button.		
		2c[e]. The BE's system creates a Performance document whose content is the information introduced by the ProfileManager and the results displayed, and assigns to it a unique identifier, *performance_id*. 3c[f]. The BE's system saves the information introduced by the ProfileManager and the results displayed by overwriting the Performance document.	
Post-Condition(s)	The Manager takes the decision to join, leave or remain in a community/CCENE or CN.		
Priority	*High*	Medium	Low
Open Issues	(1) Restrictions should be made in using the information stored in the centralized repository for negative decisions. (2) The confidentiality of the data introduced by the ProfileManager and of the results provided by the BE's system.		

[a] In case the organization does not have associated a Performance document, the activities 1a, 2a, 3a, 4a and 5a are ignored, and the BE's system displays a form which is filled in by the ProfileManager.
[b] This software program is stored in the centralized repository and executed by the BE's system. Its purpose is to compare the identifier introduced by the ProfileManager with the identifiers of all the organizations in the community. These identifiers are stored in the centralized repository.
[c] This software program is stored in the centralized repository and executed by the BE's system. Its purpose is to verify if the data submitted by the ProfileManager is of real number type.
[d] This software program is stored in the centralized repository and executed by the BE's system. Its purpose is to select the indicator(s) which may be calculated, and to calculate them. The selection of these indicator(s) is based on an algorithm that checks the potential indicators which may be calculated considering the data submitted by the ProfileManager and a set of predefined indicators; their calculation method and the input data they required are stored in the centralized repository.
[e] In case the organization does not have yet associated a Performance document.
[f] In case the organization already has associated a Performance document.

the centralized repository (e.g., the ProfileManager accesses the performance assessment service to support the Manager's decision to join a CN or not).

Table 5 portrays a formal description for the 'Access Performance Assessment Service' use case performed by the ProfileManager of an organization that is a member of the community/CCENE.

The BE's system provides a Web page where the ProfileManager introduces the identifier of the organization. The BE's system executes a software program[9] which has the purpose of comparing the identifier introduced by the ProfileManager with all the identifiers of all the organizations in the community—identifiers stored in the centralized repository. If a mach is found, two cases may be considered: (a) the organization has not assigned a

[9] This software programs executed by the BE's system is stored in the centralized repository and may be accessed and executed only by the BE's system.

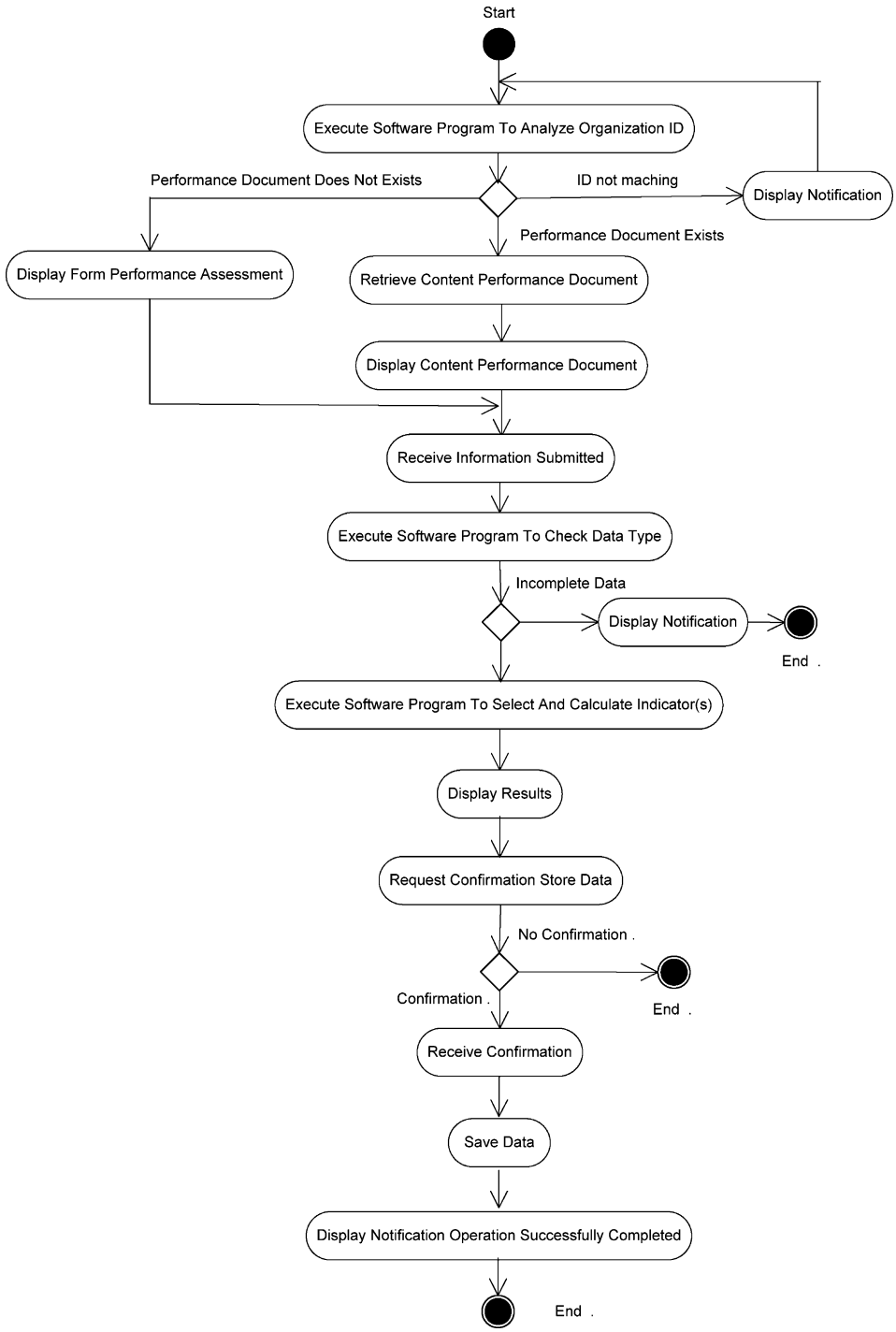

Fig. 4. Simplified flow diagram for the performance assessment service (when the organization is member of the community/CCENE).

Performance document and (b) the organization has assigned a Performance document.

For the case (a), the BE's system displays a form[10] to be filled in and submitted by the ProfileManager. A software program, whose purpose is to check if the data submitted is of natural number type, is then executed by the BE's system. If no inconsistencies are found, the BE's system executes a software program that selects the indicator(s)[11] which may be calculated based on the data submitted, and calculates these indicators. The selection of the indicator(s) is based on an algorithm that checks the possible potential indicators which may be calculated considering the data submitted and a set of predefined indicators. Their calculation model and the input data they require are stored in the centralized repository (e.g., if all the estimated costs and expected payoffs are submitted for five years, then the ROI may be calculated).

The BE's system displays the results of the performance assessment. The ProfileManager actor transmits these results to the Manager of the organization (e.g., to support his/her decision that the organization joins a certain CN).

If a confirmation for storing data is received, the BE's system stores in the centralized repository the information concerning the

[10] Example of input data so as to elaborate a performance assessment analysis is available in Annex A.

[11] Relevant indicators which may support an organization's performance assessment in a CCENE are presented in Annex B.

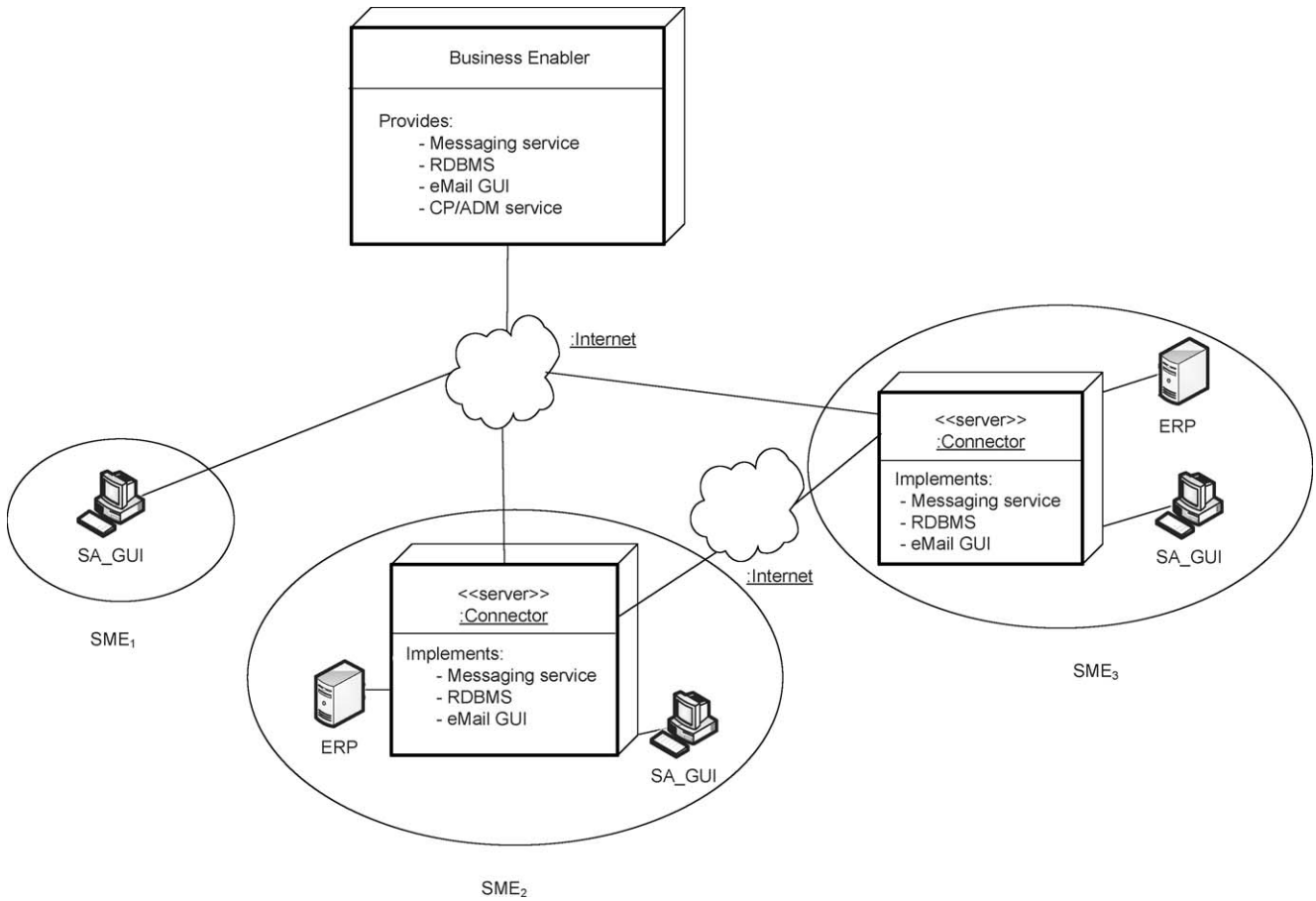

Fig. 5. System architecture (UML).

performance assessment (e.g., input data, results displayed) as a Performance document to which it assigns a unique identifier.

The case (b) has one small difference from the case (a). If the ProfileManager introduces the organization's identifier correctly, the BE's system retrieves the Performance document from the centralized repository and displays its content as a form whose fields (e.g., concerning costs and payoffs) may be changed and submitted by the ProfileManager.

Two relevant aspects should be considered. Firstly, restrictions on the use of the information stored in the centralized repository to support negative decisions should be thought, e.g., an organization in a CN uses this information to support its decision to leave the CN and join another CN. Secondly, the confidentiality of the information submitted by the ProfileManager.

Fig. 4 illustrates the main activities of the performance assessment service for the case in which the organization is a member of the community.

This service is referred to in the steps 1, 4, 6 and 7 of the interaction diagram illustrated in Fig. 3.

4. An implementation example

The aim of this section is to describe the functionality of the conceptual framework proposed with a real implementation case from the footwear industry.

4.1. Introduction

The most relevant particularities of the footwear sector have been summarized in [1,2]. The authors have presented the main actors in this sector (e.g., SMEs and Shoe Association) and their roles (e.g., supplier, manufacturer and sub-contracted SME), several business scenarios and a comparative analysis of major ICT initiatives targeting the footwear industry: EFNET (www.ef-network.org), SHOENET (www.shoenet.info), CEC-made-shoe (www.cec-made-shoe.com) EU-funded projects, emphasizing their strengths and weaknesses.[12] Accordingly, no solution is yet available to support SMEs in this sector in the negotiation and setting-up of agreements in real-time.

The ICT platform described in the next paragraphs follows previous initiatives in this sector. Its implementation has been carried out within the scope of TECMODA national R&D project (www.tecmoda.org) pursued within a partnership between the Portuguese Technological Transfer Associations (CITEVE, CTCP and ANIVEC) and INESC Porto. The Portuguese Shoe Association (SA) plays the role of Business Enabler.

4.2. System architecture

Fig. 5 illustrates the ICT platform (ShoeBiz@PT v2) implemented towards achieving seamless interoperability in the footwear sector. It comprises the messaging and CP/ADM services, a centralized repository, and the 17 SHOENET XML-based business documents especially developed for this sector. The templates of the SHOENET business documents can be downloaded by the SMEs from the centralized repository. The Shoe Association's system provides the messaging and CP/ADM services, and manages the centralized repository. The access to these services is carried out through a Graphical User Interface—GUI (SA_GUI in Fig. 5).

[12] A detailed description of the outcomes of the CEC-Made-Shoe EU IP is available in [1].

The developed ICT platform supports trading partners in conducting e-business through a reliable and secure exchange of business documents. Additional elements (e.g., APIs) may also be present. For example, external applications (e.g., ERP solutions) may use the API to send and receive business documents from other SMEs in the footwear sector.

4.3. Messaging service

The messaging service provided by the Shoe Association's system assures reliable and secure communication among SMEs within the footwear industry. Thus, the SMEs do not have to establish an agreement concerning the communication protocol to be used (this is time consuming and costly); the Shoe Association's system is responsible for the secure and reliable transmission of messages among the SMEs. This way, all the messages/business documents that are sent reach their destination in the time that was specified. However, some SMEs might choose to communicate on a peer-to-peer basis in order to increase their privacy, and specify this in the CA.

Each message encapsulates a business document. However, other documents may be attached (e.g., an annex containing technical details on the products sold).

The messaging service comprises three elements:

- a *communication Hub* assures inter-SMEs communication, and offers a set of services for the eMail application;
- a *Connector* is the link to the SMEs' ERP system, keeping track of all the business documents sent and received by the company where it is installed;
- an *eMail application* (eMail GUI) is a GUI for information management, supporting human-oriented tasks for the creation, reception and printing of the business documents. This application works as a regular e-mail front-end allowing users to send and/or receive business documents.

The ICT platform has been conceived to support three scenarios, illustrated in Fig. 6. It corresponds to the situations in which the SMEs performing e-business have or do not have an ERP: (a) two SMEs with ERP may perform e-business on peer-to-peer basis through their Connectors (Fig. 6a); (b) two SMEs without ERP will perform e-business by making use of the messaging service provided by the BE's system, which may be accessed through a GUI (Fig. 6b); (c) when two SMEs perform e-business, but only one has ERP, they exchange business documents through the messaging service made available by the BE's system, which is accessed though a GUI.

Hermes platform (www.freebxml.org/msh.htm) has been adopted as messaging service. The main reasons for this decision were as follows: it is open-source and in compliance with ebXML ebMS v2; it supports any kind of data in the body of the exchanged messages, and it supports relevant security issues (e.g., confidentiality, authentication and non-repudiation). However, Hermes has been used here in a different way. While ebXML encourages communication among the SMEs on a peer-to-peer basis, this ICT platform supports two types of communication among SMEs in the footwear sector: on peer-to-peer basis, and through a communication Hub, which allows a third-party entity (e.g., the Shoe Association in this case) to perform the role of BE.

The implementation of this service makes extensive use of open-source software: Jakarta TomCat, Hermes 2, Axis, Xerces, Castor, JGoodies and JasperReports.

Basically, the application allows the user to interact with the displayed documents in ways that are determined by the document's model. The application begins as user interactions with a form. The activities that follow are carried out by computer programs with human involvement.

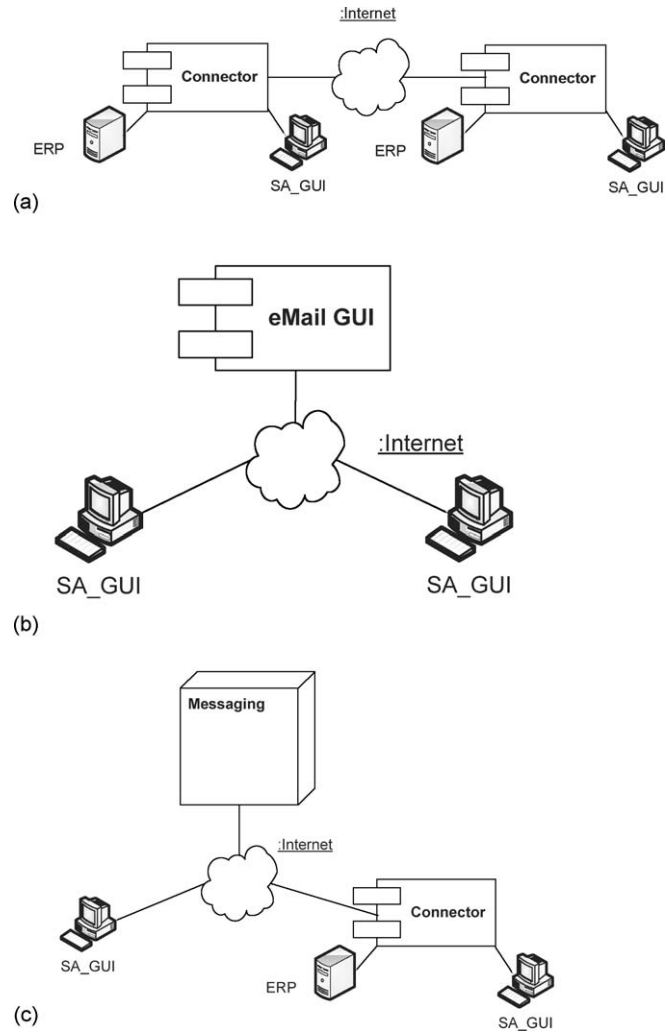

Fig. 6. Scenarios for two SMEs performing e-business (UML).

This approach emphasizes the idea of business documents as interfaces for people and inter-organizational interactions. The business documents capture the information exchanged with an e-business partner, without revealing anything about how the information is used, related or transmitted by each participant in the exchange.

Fig. 7 illustrates the user interface of the messaging service—that is ShoeBiz@PT.eMail. An *Archives* folder exists, where the user may create sub-folders and store messages. The *Employee* actor of an SME in the footwear sector may access the messages received (stored in the *Input* folder), sent (stored in the *Output* folder); messages that fail to reach their destination (in case the communication is peer-to-peer) are stored in the *Failed* folder. The messages contained in each sub-folder may be displayed in the lower part of the main screen. The content of an *Order* business document is displayed in the lower part of the main screen portrayed in Fig. 7. The information refers to: information on the business partner, who acts as buyer (e.g., the organization's name, business type); detailed information on the items, such as: model, requested delivery date, estimated delivery date and price; information on the quantity to be delivered and the size.

4.4. Management of SME collaboration profile

The access to the CP/ADM service provided by the Shoe Association's system is made through a GUI. For the *ProfileManager* actor, this application represents a HTML form displayed in

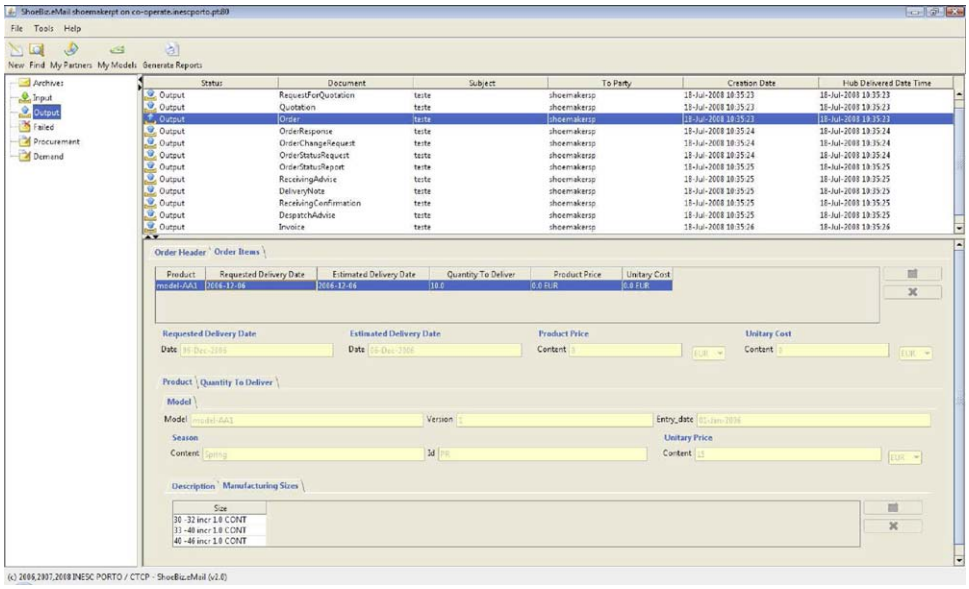

Fig. 7. Message Folders.

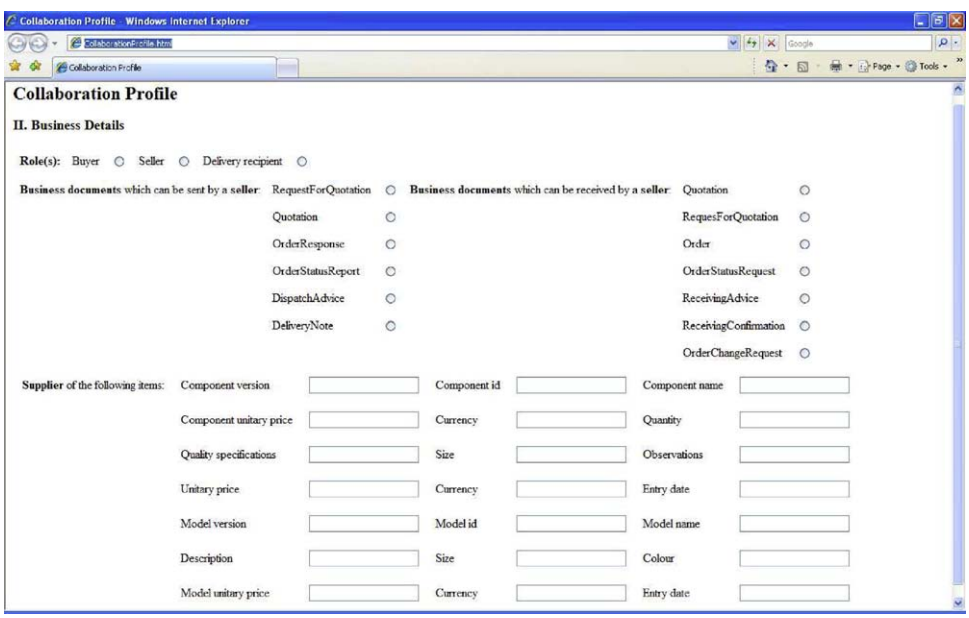

Fig. 8. Collaboration profile—business details.

a browser. The application begins when a user interacts with a form. The actions that follow are performed by computer programs with human involvement. A *ProfileManager* actor may submit, update or delete the SME's CP. The data submitted, which represents the SME's CP, refers to: general information, business details and technical details. This information is stored in the centralized repository as a document, to which a unique identifier, *cp_id*, is automatically assigned by the Shoe Association's system.

Fig. 8 presents the SME's CP fields referring to business details, for a SME with the role of seller, e.g., business documents supported to be sent and/or received, information on supplied models and components.

4.5. Business documents

Aiming at covering most of the different collaborations and relationships among the SME's in the footwear sector, a set of 17 XML-based business documents has been developed within the scope of SHOENET project to be used by ShoeBiz@PT v2 ICT platform. They can be grouped in three main categories [2]: *(a) Pre-Order Management*, comprising: RequestForQuotation, Quotation, LineProposal and TechnicalSpecificationsReport; *(b) Order Management*, with Order,[13] OrderResponse, OrderChangeRequest, OrderStatusRequest, OrderStatusReport, DeliveryNote, ReceivingInformation, Claim, DispatchAdvice and ReceivingAdvice; *(c) Payment*, comprising: Invoice, CreditNote and PreformaInvoice. These business documents represent the only data model defined for the footwear sector. They assure semantic interoperability among SMEs in the footwear industry and support cross-industry communication. However, other business documents formats can also be used.

[13] A sample of an *Order* SHOENET business document is available in [1].

Table 6
Mapping of the interoperability requirements.

No. Crt.	Name of general interoperability requirement	CIbFw	ebXML	RosettaNet	papiNet
1.	Organization's CP description	✓	✓		
2.	Organization's CP publication	✓	✓		
3.	Browse information	✓	✓		
4.	Communication	✓	✓	✓	✓
5.	Message format	✓	✓	✓	✓
6.	Business document format	✓	✓	✓	✓
7.	Connection to Internet	✓	✓	✓	✓
8.	Security	✓	✓	✓	✓
9.	Definition and specification of the inter-organizational collaborative activities	✓	✓	✓	✓
10.	Business documents	✓	✓	✓	✓
11.	Business documents choreography	✓	✓	✓	✓
12.	Negotiation	✓	✓		
13.	Agreement	✓	✓		
14.	Semantics of the exchanged information	✓	✓	✓	✓
15.	Management of the stored information	✓	✓		
16.	Availability of information	✓	✓		
17.	Compliance with legislation and national/international recommendations	✓	✓	✓	✓
18.	Conflict solving	✓			
19.	Rights and obligations	✓			
20.	Roles/Task fulfillment				
21.	Learning				
22.	Accessibility	✓	✓	✓	✓
23.	Dissemination of the specifications	✓	✓	✓	✓
24.	Performance assessment	✓			
25.	Generality	✓	✓		
26.	Comprehensibility	✓	✓	✓	✓
27.	Versioning	✓	✓	✓	✓

The messages encapsulating the business documents will be transported by an ebXML message in closed envelopes. The Shoe Association's system generates public and private keys and the exchanged messages are encrypted.

The flow of the business documents exchanged by the e-business partners is specified in the clusters of inter-organizational collaborations.

4.6. Final remarks

ShoeBiz@PT v2 ICT platform follows the specifications of the conceptual framework presented in this article and is implemented at a national level. This is the most advanced approach targeting the footwear industry. A similar approach is also being implemented at a national level for the textile/clothing industry.

5. Discussion

The CIbFw and ebXML present several similarities and differences. Like in the ebXML framework, for the CIbFw the communication is message-oriented. The CP and CA documents are stored in the centralized repository and they have the same purpose. However, unlike ebXML, which encourages the existence of several CPs for an organization (e.g., a CP to describe each role supported), the CIbFw proposes an approach where each organization has only one CP. A *performance_history* section to be included in the CP is proposed, where the result of the evaluation of a former e-business partner is saved. Also, the CIbFw supports two types of communication over the Internet: directly, on a peer-to-peer basis (like on ebXML) and through the messaging service provided by the BE's system, and provides a performance assessment service.

However, the main difference between the CIbFw and the ebXML, RosettaNet and papiNet frameworks is the existence of the BE entity, which eases e-business. The BE's system provides organizations *Software-as-a-Service*. It offers different services (e.g., messaging, CP/ADM, performance assessment) and functionalities (e.g., different filters to ease the organization's ProfileManager actor to find a suitable e-business partner, based on a set of predefined criteria, which is similar to the role played by a Broker, e.g., [4,19]). However, different from the concept of Broker, the BE and BE's system offer much more complex support to ease partnership set-up and e-business, e.g., supports conflict solving, provides messaging and CP/ADM services. The BE is not involved in the direct communications between enterprises, when they both have an ERP, as reflected in Fig. 6a. In this case, the enterprises exchange business documents without interacting with the BE.

The European Interoperability Framework, RosetaNet, papiNet, ebXML and CIbFw explore technical interoperability aspects, semantics, and inter-organizational collaborations (e.g., as organizational interoperability aspects in the case of the European Interoperability Framework). However, CIbFw is the only framework addressing business/economic interoperability aspects (as defined in Section 2.2.4). However, knowledge/information aspects are not explored in depth by CIbFw.

Semantics is addressed by CIbFw by a common set of business documents, by ebXML mainly with core components specifications or with specialized dictionaries by RosetaNet.

Negotiation and agreement issues are addressed by CIbFw and ebXML.

In order to identify the general interoperability requirements for seamless interoperability in a CCENE (which have been presented in Table 1) that are addressed by the CIbFw, ebXML, RosettaNet and papiNet,[14] a mapping has been performed (illustrated in Table 6). The CIbFw addresses all the interoperability requirements, with two exceptions: it does not deal with the organization's learning ability and roles/tasks fulfillment. In fact, these two interoperability requirements are not addressed by any of the four e-business frameworks. Conflict solving, rights and obligations, and performance assessment interoperability requirements are addressed only by the CIbFw. The CIbFw addresses approximately 92% of the general interoperability requirements

[14] These three frameworks have been selected for comparison because they are potentially the most relevant towards seamless interoperability in a CCENE, and cover industry-specific and industry-neutral frameworks.

presented in Table 1, ebXML addresses 80%, while RosettaNet and papiNet 50%. However, it is important to note that CIbFw and ebXML are horizontal approaches, while RosettaNet and papiNet are vertical initiatives.

The results of an analytical comparison of the above mentioned four e-business frameworks: CIbFW, ebXML, papiNet and RosettaNet) have been presented in [31]. The comparative analysis relies on the results obtained for an interoperability characterization function and a set of 22 criteria defined based on the general requirements for interoperability in a CCENE identified: description, publication, identification of potential business partner/opportunity, messaging, inter-organizational collaborations, negotiation and agreements, semantics, information management, conflict solving, rights and obligations, roles/tasks fulfillment, learning, performance assessment, technical specifications, comprehensibility, generality, targeted enterprise (by size), maturity, policy, accessibility, tools support, and ICT platforms. The description and scale definition of these indicators are available in [31].

The value of the interoperability characterization function obtained for the ebXML is slightly higher compared to the values attained for the other three frameworks. It is followed by the results attained for CIbFw. The lowest value has been obtained for papiNet.

The coefficient of variation[15] has also been calculated (42.37%), which shows a relatively high degree of data heterogeneity. The authors have carried out different simulation experiments, with different weights associated to each criterion and to groups of criteria. For certain cases, CIbFw has a slight advantage over ebXML, papiNet and RosettaNet (e.g., when maximum values for weights have been assigned to messaging, inter-organizational collaborations and information management criteria). However, the results obtained for the interoperability characterization function have to be carefully interpreted since these results are specific to the numerical values assumed for the parameters.

This approach for e-business frameworks comparison is one of the few existing analytical comparison tools. It provides a consistent way to identify commonalities and differences between e-business frameworks; it also emphasizes their strength and weaknesses and it is not aimed at advancing or recommending a certain initiative over the others.

6. Conclusions and future research

Research in the area of interoperability is challenging. The challenges are related to the difficulty in achieving seamless interoperability in a CCENE, to trace the adoption of different frameworks and initiatives as well as the emergence of new approaches.

Despite numerous advancements in this area and the results obtained (e.g., tools, ICT platforms and R&D projects), the objective of achieving a collaborative-networked environment where organizations are added and/or removed without requiring reconfiguration is not yet achieved. Although research on interoperability is mature in some aspects, it is still necessary to approach it with a broader scope in a systematic way, e.g., tackling economic aspects.

The main outcome of the research work pursued is a conceptual Collaborative Interoperability Framework (CIbFw) supporting seamless interoperability in a networked environment, which enables a systematic and comprehensive identification of the main steps in conducting e-business. It relies on the concept of *Business Enabler*, following a service-oriented approach. It comprises six elements: (1) a messaging service; (2) a Collaboration Profile/Agreement and Definition Management service; (3) five clusters of inter-organizational collaborative activities; (4) a centralized repository; (5) a set of business documents and contracting documents; (6) a performance assessment service. The BE's system provides SMEs *Software-as-a-Service*. CIbFw covers the main views on interoperability: technical, information/knowledge and business/economic, and addresses 92% of the general interoperability requirements identified. In order to access the services and functionalities provided by the Business Enabler's system, an initial software installation is required. Thus, seamless interoperability is achieved since the organizations which have submitted their CP to the centralized repository may be added and removed to/from a CN and can perform e-business by exchanging the agreed business documents without requiring additional reconfigurations.

Two ICT platforms are implemented at a national level following the specifications of the conceptual framework proposed, targeting the footwear and textile/clothing industries. An implementation example for the footwear industry has been presented.

The research pursued allowed to answer the main research questions that have guided this research work.

(1) *Which are the key directions to characterize and analyze interoperability in a CCENE?*

Three main directions for seamless interoperability in a CCENE have been identified: technical, information/knowledge and business/economic. Relevant approaches for each of these directions are presented in Section 2.2.

(2) *Which are the main requirements for interoperability in a CCENE?*

Twenty-seven general requirements for seamless interoperability in a CCENE have been identified and are presented in Table 1. They have been grouped in the following six core categories: description and publication; potential business partner/opportunity identification; collaboration; management; performance assessment; non-functional aspects.

(3) *How can seamless interoperability be achieved?*

Seamless interoperability in a networked environment may be achieved through the adoption of a holistic approach. The elaboration of a conceptual framework and/or an ICT platform which considers the general and industry-specific requirements for interoperability may be a solution. The existence of a Business Enabler entity may ease inter-organizational partnerships and agreements set-up, supporting CNs to achieve their goals.

The development of conceptual frameworks may be a good path towards seamless interoperability in a CCENE. Significantly, it is important to note the increasing interest in developing industry-neutral and industry-specific standards, as well as conceptual frameworks. As a consequence, it is rather difficult to decide the specifications of which conceptual framework to follow when implementing an ICT platform. A BE approach following a service-oriented architecture (like the approach presented in this research work, which supports two types of communication: directly, on peer-to-peer basis, or through the messaging service provided by the BE's system) and ebXML specifications may be considered.

Industry-specific initiatives (e.g., RosettaNet for high-tech and electronics industry, papiNet for paper and forest products industry) seem to bring a challenging and promising solution towards achieving seamless interoperability inside communities.

[15] The coefficient of variation has been calculated by using the formula: $CV = (\sigma/\mu) \times 100\%$, where σ is the standard deviation, and μ is the mean value of a population. If $CV < [30\%, 35\%]$, the data is considered homogeneous or uniform. If $CV > 35\%$, the data is heterogeneous.

However, a great challenge is to achieve cross-industry semantic interoperability. Since it would be naïve to believe that, for example, a universal dictionary or vocabulary would be adopted by all organizations/SMEs to assure full semantic interoperability, a solution may be the focus on technology. Shared efforts from different industries are necessary. Industry-specific initiatives should collaborate in order to achieve this objective. However, there is no implementation/ICT platform yet available to support seamless cross-industry interoperability. It is not realistic to believe that all business documents promoters will accept only one generic approach for building business documents. It is, however, possible that they may reach an agreement concerning the underlying technology. Another option would be transformations between business documents. However, such an approach is not desired. Firstly, because it generates errors, and secondly because transformations between different business documents of different e-business frameworks are, in some cases, impossible due to missing information.

Standard reusable patterns or elements are relevant when designing the set of business documents that are needed to carry out inter-organizational collaborative activities. In fact, they encourage the assembly of business documents from building blocks that are reused as information flows from one document into the next. In this regard, the Universal Business Language (UBL) effort promises to be an extremely important standard. In this sense, the convergence or compliance of technologies may be a solution.

XML enables the exchange of information between e-business partners. However, e-business frameworks are necessary to provide specifications on *what* information is exchanged, *how* the information is exchanged and *when* the information is exchanged [32]. This concerns the business documents to be exchanged and the inter-organizational collaboration activities, which provide the choreography of the business documents and the services used to exchange this information. A challenging question is: 'To what extent does XML support seamless interoperability in a CCENE?'

The path towards achieving full interoperability is challenging and it is rather difficult to indicate which path should be followed to achieve seamless interoperability in a CCENE. Yet, this research work has proposed a conceptual framework.

Future research will focus on business interoperability—performance assessment in a CCENE, critical factors for e-business frameworks (e.g., for the adoption and success in standardization), e-business frameworks comparison and evaluation, organizations and CNs' learning ability.

Future work will also focus on the analysis of the applicability of the CIbFw to other industry sectors,[16] and on the analysis of theories sustaining this approach.

Real data from industry will be collected in order to analyze the robustness and scalability of the information and communication infrastructures implemented.

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[16] Interest on the CIbFw approach has been manifested from a EU-funded project targeting the automotive industry.

Appendix A. An example of a form to be filled in by the ProfileManager actor so as to elaborate a performance assessment

A.1. A. Estimated annual costs (years 1–5)

- Costs concerning initial investments to join a community or CN:
  - Software
  - IT-related consultancy fees
  - Hardware
  - Manpower to control the membership process
  - Training
  - Other costs
- Management costs
  - Salary of manager
  - Other management costs
- Costs associated to risks (e.g., strategic, non-secure transactions)
- Operating costs
  - Manufacturing costs
  - Materials
  - Labor
  - Energy
  - R&D
- Product test and evaluation
  - Quality control
  - Maintenance
  - Inventory
  - Product modification
  - Product documentation
  - Waste
  - Other operating costs
- Vulnerability costs (e.g., due to errors and wrong decisions)
- Overheads
- Opportunity costs (e.g., costs associated to the selection of a less profitable alternative, from a financial point of view)
- Adhering costs (e.g., membership fees)
- Leaving costs
- Negotiation costs
- Recurring costs (e.g., costs associated with new processes)
- Communication costs (e.g., Internet, e-transaction costs and business documents processing)
- Maintenance costs (e.g., yearly software upgrades costs)
- Costs due to depreciation
- Other estimated costs
- Total estimated costs

A.2. B. Expected annual payoff (years 1–5)

- Payoff due to improved efficiency
- Payoff due to faster and cheaper access to new markets and business opportunities
- Payoff due to optimized resource allocation
- Payoff due to savings in the cost of product development
- Payoff due to increased sales
- Payoff due to decreased cost of materials
- Payoff due to faster e-communication
- Payoff due to faster agreements setting
- Payoff related to manpower (e.g., payoff due to manpower cost reduction)

Payoff due to increased information accuracy and error reduction
Total estimated annual payoff due to sales revenue growth
Payoff due to reduction in inventory holding
Payoff due to reduced total lead-times
Payoff due to business documents e-transactions (e.g., estimated annual payoff due to electronic transaction as a result of the abolishment of paper information exchange)
Payoff due to smoothening business (e.g., determined by real-time access to centralized error-free information)
Payoff due to improved services
Payoff due to improvements in employee morale
Payoff due to conflict solving (e.g., by a third party)
Payoff due to standardized information exchange (e.g., due to the use of a common set of business documents)
Estimated annual intangible benefits
Other expected payoffs
Total expected payoffs

A.3. C. Other information

Estimated inflation rate (%)
Tax on profit (%)
Other taxes (%)
Weight average cost of capital
Discount rate (%)
Total duration of the project (months)

Appendix B. Relevant indicators to support a performance assessment analysis in a CCENE

1. *Return on Investment (ROI)* is a performance measure to evaluate the efficiency of an investment. To calculate the ROI, the benefit of an investment is divided by the cost of the investment.

$$\mathrm{ROI} = \frac{\text{final\_value} - \text{initial\_value}}{\text{initial\_value}} \times 100\%$$

2. *Cost-Benefit Analysis* is a weighting scale approach for decision making. All positive elements (e.g., cash-flows) are put on one side of the balance, while all the negative elements (e.g., costs) are put on the other. Whichever weights the heavier wins.
3. *Economic value added (EVA)* is a financial performance method to calculate the economic profit of a corporation. It can be calculated as Net Operating Profit After Tax minus a charge for opportunity cost of the capital:

$$\mathrm{EVA} = NOPAT - cK$$

where: *NOPAT* is the Net Operating Profit After Tax; *c* is the Weight Average Cost of Capital, and *K* is the capital imployed
4. *Return on Invested Capital (ROIC)* quantifies how well a company generates cash flow relative to the capital it has invested. It is defined as net operating profit less adjusted taxes divided by the invested capital (which includes all monetary capital invested, e.g., financial debt, shareholders' equity).

$$\mathrm{ROIC} = \frac{\text{net\_operating\_profit} - \text{taxes}}{\text{total\_capital}} \times 100\%$$

5. *Earnings Before Interests and Taxes (EBIT)* is a measure of a firm's profitability that excludes interest and income tax expenses. To calculate the EBIT, expenses (e.g., the cost of sold goods, selling and administrative expenses) are subtracted from revenues. The profit is later obtained by subtracting the interest and taxes from the result.
6. *Net Operating Profit After Tax (NOPAT)* reflects a company's after-tax operating profit for all investors. It is defined as follows:

$$\mathrm{NOPAT} = \text{operating profit} \times (1 - \text{tax rate})$$

7. *Internal Rate of Return (IRR)* is a capital budgeting method used by firms to decide whether they should make long-term investments. It represents the annualized effective compounded return rate which can be earned on the invested capital, e.g., the yield on the investment. To find the IRR, it is necessary to find the IRR that satisfies the following condition:

$$\mathrm{NPV} = 0 = \text{initial\_investment} + \sum_{i=1}^{N} \frac{C_t}{(1+\mathrm{IRR})^t}$$

8. *Net Present Value (NPV)* is a standard method for the financial appraisal of long-term projects. It measures the excess or shortfall of cash flows, in present value terms, once financing charges are met. Therefore:

$$\mathrm{NPV} = \sum_{i=1}^{n} \frac{C_t}{(1+r)^t} - C_0$$

where t is the time of the cash flow; n is the total time of the project; r is the discount rate; C_t is the net cash flow (the amount of cash) at time t; C_0 is the capital outlay at the beginning of the investment time ($t = 0$).

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