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Collaborative business frameworks comparison, analysis and selection: an analytic perspective

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Several e-business frameworks are currently available, which are aimed at modelling e-business. The aim of this article is to analyse and compare relevant industry-neutral and industry-specific e-business frameworks currently in use, emphasising their strengths and weaknesses towards seamless interoperability in a collaborative networked environment. Their main differences and similarities are underlined based on an analytical model for e-business frameworks comparison. The applicability of the Analytic Hierarchy Process multi-criteria method in e-business frameworks selection is discussed. These analytical approaches are then illustrated with two real cases from industry.

Keywords: e-business framework; collaborative networks; analytical comparison; footwear and textile/clothing industry; analytic hierarchy process

1. Introduction

The adoption of the Internet, the developments of the information and communication technologies (ICTs), the growth of the Web and its ubiquity and affordability, and economic factors have compelled organisations to examine their strategies and adapt their ways of undertaking business. As a consequence, the businesses have migrated from traditional practices to e-business, and new forms of collaboration have emerged, such as collaborative networks (CNs) (e.g., Chituc *et al*. 2007, 2008b). The CNs have appeared in a large variety of forms, such as virtual organisations, virtual enterprises (VEs), industry clusters, virtual communities, collaborative virtual laboratories and virtual organisation breeding environments (e.g., Abreu and Camarinha-Matos 2008, Camarinha-Matos and Afsarmanesh 2008).

CNs represent collections of heterogeneous organisations, which join their resources for a determined period of time in order to achieve a common objective (e.g., Stanescu *et al*. 2002, Camarinha-Matos and Afsarmanesh 2003, Huang and Wu 2003, Tsai *et al*. 2004, Chituc and Azevedo 2006, Chituc and Nof 2007). The idea of CNs/VEs is not new and has been used in several industry sectors for many years (e.g., Davidow and Malone 1992, Molina *et al*. 2007). However, great challenges are related to achieving seamless interoperability, and the selection and implementation of an appropriate e-business framework or standard.

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In this research work, the term *e-business* refers to inter-organisational activities that lead to added value and are conducted using the Internet. These collaborative activities are determined by electronic interactions between business partners, e.g., who exchange messages over the Internet by making use of ICTs. Thus, the notion of e-business includes concepts like business-to-business, e-commerce, business-to-customer and business-to-government.

The purpose of e-business is to increase the organisations' added value through inter-organisational collaborations, improving the use of resources, reducing the costs and time, and increasing the quality of the products or services provided, by using ICTs. Its current scale can be perceived in different domains, e.g., healthcare, travel, footwear, textile, food, paper, high-tech industry.

Seamless interoperability[1] among heterogeneous and geographically distributed systems will allow the networked organisations to transmit, combine and process shared information, a task where e-business frameworks can assist in many ways (e.g., Nurmilaakso *et al*. 2006, Chituc *et al*. 2008b, 2009). E-business frameworks provide exact details on what information to exchange (e.g., the business documents to be exchanged and their choreography) and the messaging mechanism. They enable a shared understanding of the inter-organisational interactions by providing a set of specifications. An e-business framework is, in fact, a set of specifications for inter-organisational information sharing, which support organisations to perform e-business. As emphasised by Nurmilaakso (2008b), an e-business framework is a high-level standard for e-business, which makes use of a data format to define data structures, data elements and their purposes in a business context.

Achieving seamless interoperability in a collaborative networked environment (CNE) requires adequate frameworks, technologies and ICT platforms to support, in a natural way, inter-organisational operations and real time information exchange, a proper technological and managerial alignment (e.g., of intra- and inter-organisational activities, partners' individual actions, goals and strategies, with the common strategic objectives of the CN), adequate models and tools for performance monitoring and assessment, and a common agreement on performing e-business, e.g., when and how to exchange information. In this way, independent organisations can work as a single entity and attain a common objective, while pursuing their individual goals.

E-business frameworks can support organisations to decrease costs, shorten the time to agree on e-integration details, and enable inter-organisational interactions to perform e-business. They provide specifications in a way which is independent of individual organisation's type or size, technologies, system architectures, or industry. They may refer to technological aspects, but not restricted to them.

A natural question which may rise is: 'why do we need sophisticated technologies, e-business frameworks, and ICT platforms towards seamless interoperability taking into account that some enterprises have used standards for over 20 years to perform business with their partners?' The answer lies in the increasing complexity of ICTs, increasing competition, and increasing client demands (e.g., concerning time, cost, quality of products or services) with which enterprises have currently to deal with.

Several e-business applications, frameworks, ICT platforms and standards aiming at achieving seamless interoperability in a CNE have been developed, which are promoted by companies, vendors, and not-for-profit organisations and consortia. They aim at providing industry-specific or industry-neutral standards which can be easily adopted by enterprises. However, different technology developments addressing interoperability

have generated a huge variety of approaches, which are difficult (or sometimes impossible) to be integrated and managed. As pointed out by Bussler (2003), the enterprises which are looking for an integration solution are confronted with a fragmented landscape of integration technology.

In this context, real growing problems are related to e-business frameworks selection and achieving interoperability between different business partners using different and incompatible e-business solutions and standards (e.g., Bussler 2003). This article pertains to address these issues focusing on e-business frameworks analysis, analytic comparison and selection. So far, relatively scarce research has been pursued in these areas. Therefore, in this article we endeavour to develop an analytical approach for e-business frameworks comparison, and propose the Analytic Hierarchy Process multi-criteria method to support e-business frameworks selection.

1.1 *Aim and main research questions*

The aim of this article is to develop an analytical model to support e-business frameworks analysis and comparison.

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

(1) Which are the most relevant industry-neutral and industry-specific e-business frameworks currently in use?
(2) How can e-business frameworks be compared?
(3) Do e-business frameworks compete or complement each other?
(4) Which are the main differences and similarities between existing e-business frameworks?
(5) Which criteria and/or method(s) may be used to support a decision maker or developer in selecting an e-business framework?

By attempting to answer these questions, 22 comparison criteria have been determined, which have been identified considering the gap analysis for interoperability described by Chituc *et al*. (2008b), and the 27 general requirements for interoperability in a CNE presented by Chituc *et al*. (2009). An interoperability characterisation function has also been constructed, which supports e-business frameworks, analytical comparison. The applicability of the Analytic Hierarchy Process (AHP) multi-criteria method for e-business frameworks selection is then discussed. These two analytical approaches are then exemplified with real cases with data collected from TECMODA (2006) project leader.

1.2 *Related work/background*

Although there is a high interest on interoperability in a CNE and e-business, and active research is pursued on the emergence of e-business frameworks and standards, which is reflected by numerous R&D projects in this area (e.g., ECOLEAD 2004, ATHENA 2007) and the relatively high number of articles published, research focusing on e-business frameworks comparison is relatively scarce.

Most research studies on e-business frameworks are more descriptive than comparative (e.g., Li 2000, Shim *et al*. 2000, Zhao and Sandhal 2000, Hasselbering and Weigand 2001).

A general and component based comparison of four e-service frameworks (eCo, RosettaNet, BizTalk, and e-speak) has been presented by Kim *et al*. (2003). For the

general comparison, the following criteria have been considered: the targeting industry and purpose, metadata and ontology, standard XML efforts, and legacy support. The component-based comparison is made in terms of service discovery, service brokering, service negotiation, service mediation, service billing, service payment, service component, and service security. This comparative analysis tackles only technical aspects related to interoperability. Only technical aspects on interoperability have also been analysed by Dogac and Cingil (2001). The study focuses on eCo framework, RosettaNet, BizTalk, cXML and MESChain. However, the criteria used are relatively limited (e.g., considering current developments of the selected e-business frameworks).

A conceptual framework for business-to-business protocols comparison used to compare WSDL (2001) and ebXML (2008) approaches for protocol specifications is described by Bernauer *et al.* (2003). The layers of the conceptual framework considered are: services, interactions, documents, and information items. The authors conclude that there is no direct interoperability between the WSDL and ebXML-based approaches, neither conceptually or operationally.

Other studies are focusing mainly on standardisation, in general, rather than on frameworks comparison. A conceptual framework targeting vertical e-business standards and standards developing organisations has been introduced by Zhao *et al.* (2005). However, the focus of the research work is on the analysis of standard developing organisations and not on the properties of the standards. Two other studies focusing on standardisation in general have been presented by Jakobs *et al.* (1998) and Jakobs (2002). Jakobs *et al.* (1998) emphasise that companies with different cultural backgrounds are likely to have very heterogeneous needs and requirements, as they represent their own interests. Jakobs (2002) points out that standardisation takes place in markets and committees, and users seem to adopt the technology assuming that it represents a standard because it is the most widely adopted. Farrell and Saloner (1988) stressed that the markets are faster, but committees cause fewer errors in standardisation. However, hybrids of the committee and market are more efficient than committees. Network effects emphasised by the economics of standards are discussed by Katz and Shapiro (1985). The organisational assimilation of vertical standards is analysed by Mendoza and Ravichandran (2007).

A comparison and evaluation of ebXML and RosettaNet frameworks based on a model specified for small and medium enterprises (SMEs) has been introduced by Pusnik *et al.* (2002), and Pusnik and Juric (2002). A general overview and a formal comparison of ebXML and RosettaNet based on their features is made by Pusnik *et al.* (2003a), where 15 comparison criteria have been identified. The two frameworks have been compared based on their 'utility function'. Although this article represents one of the very few studies introducing an analytical approach for e-business frameworks comparison, the model has two major limitations. Firstly, the criteria identified are limited, and not all have a high relevance. Secondly, the model proposed does not admit a hierarchy or preferences for the comparison criteria. The authors do not make a clear distinction between framework specifications and implementation specifications. Besides, some of the criteria may be useful for comparing technologies, but they are not satisfactory to compare e-business frameworks.

The XLANG (2008), WSFL (2008), BPEL4WS (2002), WSCI (2002), ebXML BPSS and BPML (2008) are compared by Pusnik *et al.* (2003b), based on 10 patterns, which are actually used to describe the workflow in business processes. The authors carry out the comparison based on a 'utility function'.

For the properties of the XML-based e-business frameworks, three technical variables have been identified by Medjahed *et al.* (2003), Nurmilaakso and Kotinurmi (2004), and Nurmilaakso *et al.* (2006): business documents, business processes, and messaging. The business documents concern the information to be exchanged: if an e-business framework provides means to define generic business documents, then it is based on a generic document approach. A specific document approach defines particular business documents (e.g., for a specific industry sector). In a similar way, business processes may be generic or specific. The messaging concerns issues on how the business partners share information (e.g., by making use of ebXML's messaging service, ebMS, or RosettaNet Implementation Framework, RNIF).

A conceptual framework developed for the systematic evaluation of interoperability standards is introduced by Mykkanen and Toumainen (2008). The proposed framework is based on models found in literature on enterprise system architectures, interoperability, and product and standards evaluation. The main interoperability levels considered are: technical interfaces, technical infrastructure, application infrastructure, functional interfaces, semantics, functional reference model, and application life-cycle interfaces. The framework is used through nine evaluation forms. However, aspects related to business/economic interoperability are not considered.

A study exploring organisational and technological factors influencing the adoption of e-business functions and migration from EDI-based to XML-based e-business frameworks in supply chain integration is available in Nurmilaakso (2008a).

1.3 *Organisation of article*

The rest of this article is organised as follows: an overview of relevant industry-neutral and industry-specific e-business frameworks is available in the next section. Section 3 describes an approach supporting the e-business frameworks analytical comparison, based on a proposed interoperability characterisation function. The applicability of the Analytic Hierarchy Process for e-business frameworks selection is analysed in Section 4, where the methods presented are applied to two real cases from TECMODA (2006) project. The results of the e-business frameworks comparison are then discussed in Section 5. The paper concludes with a section addressing the needs for further research.

2. E-business frameworks: an overview

2.1 *Introduction*

Numerous industry-specific and industry-neutral e-business frameworks and standards have been elaborated to support enterprises to perform e-business and achieve seamless interoperability in a networked environment, without fully achieving this objective (e.g., Pollock 2001, Chituc *et al.* 2008b).

As emphasised by Nurmilaakso (2008b), before the Extensible Markup Language (XML), the standards for e-business were known as Electronic Data Interchange (EDI) standards or simply EDI. EDI provides a common platform by which trading partners can perform inter-company computer-to-computer documents in standard formats (e.g., Hinge 1988). XML (1998) describes a class of data objects called XML documents and partially describes the behaviour of computer programs which process them. Unlike EDI,

XML-based approaches were specified for Internet environments, require a low initial investment, are optimised for easy programming and readability, require a web server (and not a dedicated EDI server, which is much more expensive), have an easy to learn file format and the documents are self describing.

Due to these advantages, several XML-based e-business frameworks have been proposed by industry and different consortia. The most relevant ones are presented in the following subsections[2]. A more in depth description and analysis of ebXML and industry-specific initiatives are available in Chituc *et al.* (2008b); the authors also emphasise the main strengths and weaknesses of these initiatives towards seamless interoperability in a CNE.

2.2 *ebXML*

ebXML (2008) is a modular suite of specifications aimed at enabling e-business over the Internet. It targets enterprises of all sizes, independent of the industry sector. It provides specifications for messaging (ebMS); registry/repository; business process specification schema (BPSS), collaboration partner profile agreement and core components. The number of software implementations following its specifications is relatively high (e.g., Hermes H2O 2008). The ebMS defines a standard communication protocol for the reliable and secure exchange of messages between e-business partners over the Internet and uses the SOAP (2000).

2.3 *CIbFw*

The Collaboration Interoperability Framework (CIbFw) aims at supporting seamless interoperability in a CNE (e.g., Chituc 2008, Chituc *et al.* 2009). It has been elaborated to answer the general requirements for interoperability and the gap analysis presented by Chituc *et al.* (2008b).

It comprises six elements: (1) a messaging service, which assures e-communication among organisations; (2) a collaboration profile/agreement definition and management service responsible for the definition and management of the organisations' collaboration profiles and agreements; (3) five main clusters of collaborative business activities; (4) a centralised repository; (5) a set of business documents and supporting documents; and (6) a performance assessment service. The CIbFw relies on the concept of Business Enabler (BE), which is an entity with the sole purpose of easing organisations in performing e-business by providing different services, e.g., messaging.

CIbFw's specifications are used for the development of two ICT platforms targeting two industry sectors in Portugal: the footwear, and textile/clothing industries within the scope of TECMODA (2006) R&D national project.

2.4 *ATHENA interoperability framework*

ATHENA interoperability framework has been developed within the scope of ATHENA (2007) EU-funded research project. It addresses research challenges identified in each layer of the IDEAS Framework within the scope of IDEAS Roadmap (2002).

2.5 *TexWeave and Moda-ML*

TexWeave (2005) is a standardisation initiative aiming at providing an interoperability framework for the textile/clothing sector. It has been built upon the results of the WS/TEX-SPIN and other pilot projects. The business documents are specified through XSD (2001).

Moda-ML (2008) specifies an interoperability framework, based on the ebXML, to enhance collaboration and interaction inside the textile/clothing supply chain.

LEAPFROG (2005) EU IP is expected to create a sector ontology from the (ISO11179 compliant) dictionary of TexWeave and Moda-ML (Onto-Moda).

2.6 *The footwear industry*

Relevant initiatives towards seamless interoperability in the footwear industry are listed below.

The SHOENET platform (2008) has been developed within the scope of SHOENET European R&D project. It comprises two main elements: a messaging platform able to integrate SME's ERP (enterprise resource planning) systems through the internet; and a set of 17 XML-based business documents especially designed for the targeted sector.

CEC-made-shoe EU Integrated Project (2004) has two main outcomes: a messaging infrastructure, and a business process layer assuring business processes' coordination and choreography (e.g., Chituc *et al*. 2008b). This approach makes use of the SHOENET business documents.

The ShoeBiz (2006) ICT platform is the result of a Portuguese project whose aim is to promote the electronic integration of the companies in the footwear industry through a secure Internet-based communication infrastructure. It allows the exchange of SHOENET business documents between companies, and uses the ebMS as the main communication protocol. The platform is currently installed in Portugal, and is compliant with SHOENET platform (Chituc *et al*. 2007).

2.7 *Final remarks*

Although specifications/standards should be relatively static (e.g., in order to allow software products to be compliant), they do change (e.g., release of versions).

The high diversity of e-business frameworks creates selection problems. Businesses trying to adopt a certain standard are confronted by a variety of standards and e-business frameworks, which point in different directions. Thus, an analytical comparison method would help decision-makers in understanding the main characteristics of an e-business framework, its strengths and weaknesses, assisting them in the selection process.

3. E-business frameworks analytic comparison

The following subsections present an analytical approach to compare e-business frameworks (a first version of these proposed criteria and interoperability characterisation function have been presented by Chituc (2008) and Chituc *et al*. (2008a)). Twenty-two criteria have been identified and an interoperability characterisation function has been defined. The results obtained by comparing four e-business frameworks supporting interoperability in a CNE are presented and discussed.

3.1 *Criteria definition*

In order to elaborate an analytic comparison of e-business frameworks, a set of 22 criteria has been identified. The definition of these criteria (Ci [3]) is based on an extensive literature review, the views and attributes for seamless interoperability, the main requirements for interoperability in a CNE presented by Chituc *et al.*(2008a, 2009), and the gap analysis detailed by Chituc *et al.* (2008b).

The 22 criteria have been grouped into seven groups: (*G*1) *description and publication* addresses the ability of a framework to refer to aspects related to the description and publication of an organisation's collaboration profile (CP) and comprises two criteria: (C1) description, and (C2) publication; (*G*2) *search/browse information* concerns the ability of a framework to address aspects related to the identification of potential business partners or opportunities, and comprises one criterion: (C3) identification of potential business partner/opportunity identification; (*G*3) *collaboration* addresses the ability of a framework to refer to aspects related to inter-organisational collaboration (e.g., messaging, negotiation, agreements) and contains four criteria: (C4) messaging, (C5) inter-organisational collaborations, (C6) negotiation and agreements, and (C7) semantics; (*G*4) *management* concerns the ability of a framework to address management issues (e.g., information management, conflict solving) and comprises five criteria: (C8) information management, (C9) conflict solving, (C10) rights and obligations, (C11) roles/tasks fulfilment, and (C12) learning; (*G*5) *performance assessment* concerns the ability of a framework to address aspects related to performance assessment and contains one criterion: (C13) performance assessment; (*G*6) *specifications* concerns the specifications of a framework (e.g., amount of supporting literature, comprehensibility) and includes seven criteria: (C14) technical specifications, (C15) comprehensibility, (C16) generality, (C17) targeted enterprise (by size), (C18) maturity, (C19) policy, and (C20) accessibility; (*G*7) *implementations* concerns the tools and ICT platforms developed by following the specifications of a framework and comprises two criteria: (C21) tools support, and (C22) ICT platforms.

Table 1 illustrates the 22 comparison criteria and their scale definition. A more detailed description is available in Chituc (2008).

3.2 *The interoperability characterisation function*

A weight coefficient may be assigned to each criterion, since a certain manager, stakeholder or decision maker may prefer certain criteria over the others. With these considerations, an interoperability characterisation function C_f has been defined to support the analytical comparison of e-business frameworks, as follows:

$$C_f : F \times \Re \rightarrow \Re_+^*$$

$$C_f(F_j; w_i) = \sum_{\substack{i \in I \\ \max(Ci(F_j)) \neq 0}} \frac{Ci(F_j)^* w_i(Ci)}{\max(Ci(F_j))} + \sum_{i \in P} Ci(F_j)^* w_i(Ci), \quad (1)$$

where F is the set of frameworks to be compared. The weight w_i assigned to a specific criterion Ci has been represented with w_i(Ci); Ci is the ith criterion[4], and $i \in \mathbf{N}^*$; F_j is the framework alternative, $F_j \in F$, and $j = \overline{1,n}$ where $n \in \mathbf{N}^*$ is the total number of frameworks to be compared; w_i(Ci) $\in \Re$, and $I = \{7, 14, 15, 16, 17, 18, 19, 20, 21, 22\}$ and $P = \{1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13\}$.

Table 1. Criteria description and scale definition.

Criterion id	Name	Description	Scale definition
C1	Description	It evaluates the ability of a framework to address aspects related to the description of an organisation (e.g., information to be included in an organisation's collaboration profile).	1 – Yes 0 – No
C2	Publication	It evaluates the ability of a framework to address issues related to the publication of an organisation's collaboration profile.	1 – Yes 0 – No
C3	Identification of potential business partner/opportunity	It evaluates the ability of a framework to address issues related to the identification of potential business partner(s) or opportunity (e.g., search for a potential business partner in a centralised repository).	1 – Yes 0 – No
C4	Messaging	It evaluates the ability of a framework to address issues related to the communication between different organisations/systems, e.g., message exchange.	1 – Yes 0 – No
C5	Inter-organisational collaborations	It evaluates the ability of a framework to address issues related to the description/specification of inter-organisational collaborations.	1 – Yes 0 – No
C6	Negotiation and agreements	It evaluates the ability of a framework to address issues related to the negotiation and establishment of a collaboration agreement between two organisations in order to perform e-business.	1 – Yes 0 – No
C7	Semantics	It evaluates the ability of a framework to address issues related to semantic interoperability, e.g., cross- and intra- industry semantic interoperability.	2 – Cross- and intra-industry semantic interoperability 1 – Intra-industry semantic interoperability 0 – It does not tackle semantic interoperability issues
C8	Information management	It evaluates the ability of a framework to address issues related to information management.	1 – Yes 0 – No

Table 1. Continued.

Criterion id	Name	Description	Scale definition
C9	Conflict solving	It evaluates the ability of a framework to address issues related to solving potential conflicts (e.g., concerning message repudiation).	1 – Yes 0 – No
C10	Rights and obligations	It evaluates the ability of a framework to address aspects related to the rights and obligations of an organisation in a CNE/CN (e.g., access rights).	1 – Yes 0 – No
C11	Roles/tasks fulfilment	It evaluates the ability of a framework to address aspects related to organisation's fulfilment of roles/tasks.	1 – Yes 0 – No
C12	Learning	It evaluates the ability of a framework to address aspects related to an organisation/CN's learning ability.	1 – Yes 0 – No
C13	Performance assessment	It refers to the ability of a framework to address issues related to performance assessment.	1 – Yes 0 – No
C14	Technical specifications	It evaluates the amount of supporting literature and examples available (e.g., technical reports, scientific articles), which facilitate a framework's understanding.	3 – High number 2 – Average 1 – Low number/ 0 – Zero
C15	Comprehensibility	It evaluates the effort (e.g., time, work) necessary to understand a framework's specification.	3 – Low effort 2 – Average 1 – High amount of effort

C16	Generality	It evaluates the degree of generality of a framework, e.g., considering the possibility to adapt it to the requirements of a certain industry.	3 – Low 2 – Average 1 – High.
C17	Targeted enterprises (by size)	It refers to the type of enterprises targeted by a framework.	3 – Supporting enterprises of all sizes 2 – Mostly for SMEs 1 – Mostly for large enterprises
C18	Maturity	It evaluates the maturity or recognition of a framework, based on the number of years since the first technical specification has been published.	Number of years since the first specification has been published or presented.
C19	Policy	It characterises the degree in which the framework follows national/international legislation and recommendations.	3 – High 2 – Average 1 – Low
C20	Accessibility	It characterises the degree in which the specifications of a framework are available for different organisations.	3 – High 2 – Average 1 – Low
C21	Tools support	It refers to the quantity of support tools designed and implemented to facilitate the development of infrastructures considering a certain framework as basis.	3 – High number 2 – Average 1 – Low number 0 – Zero
C22	ICT platforms	It refers to the quantity of ICT platforms developed by following the specifications of a framework.	3 – High number 2 – Average 1 – Low number 0 – Zero

Note: A first version of these proposed criteria and scale definition has been presented by Chituc (2008) and Chituc *et al.* (2008a).

3.3 *Results*

The results obtained for the interoperability characterisation function by comparing the four frameworks[5]: CIbFw, ebXML, RosettaNet and papiNet, for the case when the weight assigned to each criterion was equal (which means there is no preference for one criteria over the others), have been discussed by Chituc (2008) and Chituc *et al.* (2008a).

The results were as follows. The obtained value of the interoperability characterisation function for the ebXML was higher when compared to the values attained for the other three frameworks. It was followed by the values acquired for the CIbFw. The lowest value of the characterisation function has been scored with papiNet. The CIbFw addresses all criteria, with two exceptions: (C11) roles/task fulfilment, and (C12) learning. These two criteria are not addressed by any of the four frameworks analysed. Criteria (C13) performance assessment, (C9) conflict solving, and (C10) rights and obligations are addressed only by the CIbFw.

The mean values[6] and the standard deviation[7] have been calculated. The mean value was 12.02 and the standard deviation was 5.17, which illustrate a relatively high distribution of the data from the mean value. The coefficient of variation[8] was 42.37%, which shows a relatively high degree of data heterogeneity.

The results obtained must be carefully interpreted, since the selection of these comparison criteria is based on the definition of seamless interoperability and the general requirements for interoperability presented by Chituc *et al.* (2009). In addition, the weighted values associated to each criterion were considered to be equal. Thus, the values obtained for the interoperability characterisation function are specific to the numerical values assumed for the parameters.

Analysing the results obtained for each group of criteria, the CIbFw specifications tackle all seven groups of criteria. The CIbFw is the only framework addressing the group of criteria (G5) performance assessment. For the group of criteria (G4) management, the highest value has been obtained for the CIbFw. For the groups of criteria (G6) specifications and (G7) implementations, higher values have been obtained for ebXML. With respect to the number of implementations (e.g., tools, ICT platforms), the lowest values have been obtained by CIbFw. This can be explained by the fact that ebXML, RosettaNet and papiNet are more mature initiatives (e.g., RosettaNet specifications were first published eight years before the first presentation about CIbFw had been made).

Figure 1 illustrates the relative interoperability intensity, with respect to the interoperability characterisation function for the groups of criteria of the e-business frameworks considering the seven groups of criteria presented in Section 3.1: (G1) description and publication; (G2) search; (G3) collaboration; (G4) management; (G5) performance assessment; (G6) specifications; (G7) implementations.

The values obtained for the interoperability characterisation function may be used by a decision maker to support his/her decision to select a certain framework: e.g., the framework for which the highest value of the interoperability characterisation function has been obtained will be selected.

Variable values can be assigned to the weight associated to each criterion $w_i(C_i)$, which represent the relative importance associated to criterion C_i. Different simulation experiments have been carried out by assigning different weights to individual criteria, which are described by Chituc (2008). The results obtained illustrated that the adoption of a certain e-business framework depends on the importance associated to each criterion.

For example, certain decision makers may assign a higher importance to criteria related to specifications or maturity, than to rights and obligations. In this case, the highest value of the interoperability characterisation function is obtained for ebXML, thus a decision maker may select ebXML. When a decision maker assigns higher weights to criteria or groups of criteria related to management and performance assessment, the highest value of the interoperability characterisation function is obtained for the CIbFw, indicating that the decision maker should select this framework. However, these results have to be interpreted with care, since they are specific to the numerical values considered.

4. The Analytic Hierarchy Process and e-business frameworks selection

This section illustrates the applicability of the Analytic Hierarchy Process (AHP) multi-criteria method in assisting a decision maker in selecting an e-business framework.

The aim of the following subsections is to emphasise that a multi-criteria approach, such as the AHP, can be used to select an e-business framework, considering the criteria and groups of criteria presented in Section 3.1 and Table 1 and not to indicate that a certain e-business framework is superior[9]. The results obtained considering real data from industry are then discussed.

4.1 *The Analytic Hierarchy Process: an overview*

The AHP proposed by Saaty (1980, 1987, 1997) is an approach of multi-criteria decision making. Accordingly, a decision can be abstracted on deriving weights or rankings, and by synthesising the priorities for a set of alternatives, according to their impact on a certain situation, the criteria of the decision, and the goal set. It uses hierarchic or network structures to represent a decision problem. At each level of the hierarchy, pairwise comparisons of decision elements are used to arrive at priority scores of the elements under consideration. A brief overview of the AHP methodology is available in Appendix 1.

The AHP method has been successfully applied to different domains along the years to support decision or selection problems, e.g., software engineering, as presented by Davis and Williams (1994), and Li *et al.* (2006); e-commerce, as presented by Kong and Liu (2005); medicine as illustrated by Sloane *et al.* (2002); investment appraisal, as discussed by

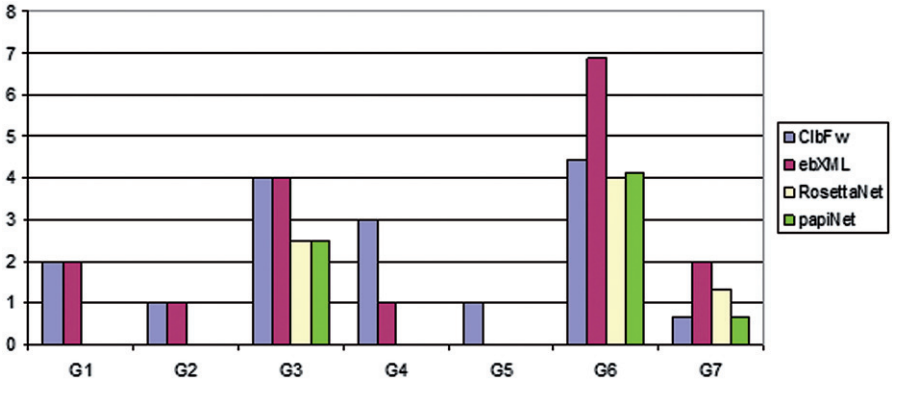

Figure 1. Results of the interoperability characterisation function.

Frazelle (1985), Wabalickis (1988), and Mohanty and Venkataraman (1995); performance measurement, as illustrated by Rangone (1996), and several software packages are available to implement the AHP, e.g., Buede (1993). It handles multiple criteria with relative ease, considering quantitative and qualitative data. Several studies aimed at comparing or assessing multi-criteria methods indicated its superiority, e.g., Akhavi and Hayes (2003).These represented the reasons for selecting the AHP to elaborate this analysis for e-business frameworks selection.

4.2 *E-business framework selection: two cases from industry*

The aim of this section is to illustrate the applicability of the interoperability characterisation function and the AHP method in the analysis, comparison and selection of an e-business frameworks with two real cases from industry, which are targeting the footwear, and textile/clothing industries.

4.2.1 *TECMODA R&D project*

TECMODA (2006) R&D project pursued at national level targets two industry sectors: footwear, and textile/clothing industries. It aims at achieving seamless interoperability among SMEs in these industry sectors and is pursued in partnership between the Portuguese Technological Transfer Associations (CITEVE, CTCP, ANIVEC) and INESC Porto.

The ICT platforms implemented follow the specifications of the collaboration interoperability framework, CIbFw, proposed by Chituc (2008) and Chituc *et al*. (2009). However, only two services of the CIbFw are implemented: the messaging and Collaboration Profile/Agreement Definition and Management (CP/ADM) services. The business partners perform e-business by exchanging business documents, following the specifications of the inter-organisational collaborative business activities and a predefined choreography of the business documents. For the footwear industry, a set of 17 XML-based business documents especially developed for this sector within the scope of SHOENET EU-funded project are used. The business documents used for the textile/clothing industry are provided by TexWeave initiative.

The system architecture and ICT platform of both approaches rely on the concept of Business Enabler (BE)[10]. The Business Enabler represents an entity within the CNE which eases inter-SMEs' partnerships and agreements setting and management. Its main responsibilities include (but are not limited to): to solve potential conflicts (e.g., due to message repudiation), to disseminate the initiative, to manage the portal where public information is available to organisations. The Business Enabler's system may perform the following tasks: stores information in the centralised repository, manages the centralised repository (e.g., manages information related to SME's collaboration profile and collaboration agreements, access rights), provides different services to SMEs (e.g., messaging, CP/ADM), provides templates of business documents and supporting documents, signs the final collaboration agreement. The Portuguese Shoe Association performs the role of business enabler for the footwear industry, and the Portuguese Textile Association for the textile/clothing industry, respectively.

Figure 2 illustrates the system's architecture. The BE's system manages the centralised repository and provides the messaging and CP/ADM services for the SMEs in each sector. The SMEs access these services through a graphical user interface (GUI), noted with

BE_GUI. Each SME is responsible for managing its local database (relational database management system, RDBMS).

Both ICT platforms (targeting the footwear and textile/clothing industries) are implemented to support three scenarios, which correspond to the cases when the two SMEs performing e-business have or do not have an ERP. The ICT platforms support SMEs in conducting e-business over the Internet, reliably and securely. Additional elements (e.g., APIs) may also be present: e.g., external applications, such as ERP solutions, may use the API to send and receive business documents to/from other SMEs in these sectors. The messaging service comprises three elements: a communication hub, which assures inter-SME communication, a connector, which is the link to the SMEs' ERP system, and an email application (eMail GUI), which is a GUI for information management, supporting human-oriented tasks for business documents' creation, reception and printing.

The implementations are making extensive use of open-source software: Jakarta, Tomcat, Hermes (2008), Axis, Xerces, Castor, JGoodies, JasperReports. Hermes H2O platform has been adopted as the messaging service. The main reasons for this choice were: it is an open source and in compliance with ebXML ebMS v2, supports any kind of data in the body of the exchanged messages and provides a second communication channel, EDIINT-AS2 (2008). However, Hermes H2O is used here in a different way: while ebXML encourages communication among SMEs on a peer-to-peer basis, the ICT platforms implemented within the scope of TECMODA project support two types of communication among SMEs in the footwear and textile/clothing industries: 1) on a peer-to-peer basis, 2) through a communication hub which allows a third party entity to perform the role of Business Enabler (e.g., the Portuguese Shoe Association in the case of the footwear industry).

The next subsections describe results of the analysis of the following e-business approaches: CIbFw and ebXML as industry-neutral approaches, CEC-made-shoe for the footwear industry, and TexWeave/Moda-ML initiatives for the textile/clothing industries, considering their particularities, strengths and weaknesses for these industry sectors. The results are based on the data gathered from the ICT platform development project coordinator of the TECMODA R&D project (which performs in this case the role of decision maker).

4.2.2 *Results for the interoperability characterisation function*

Table 2 illustrates the results obtained for the interoperability characterisation function considering the weights assigned to individual criteria[11] and groups of criteria for both footwear and textile/clothing industries by TECMODA ICT platform development project coordinator. The standard deviation, mean values and coefficients of variation have also been calculated.

For the footwear industry, for weights assigned to individual criteria (Formula (1)), the maximum value for the interoperability characterisation function has been obtained for ebXML (63), followed by CIbFw (60.31). The lowest value has been obtained for CEC-made-shoe approach (28.97). The standard deviation is 18.91, and the coefficient of variation is 37.25%, which reflects a slight data heterogeneity. For weights assigned to groups of criteria, the highest score has been obtained for ebXML (24), followed closely by CIbFw (23.66). The lowest score has been attained for CEC-made-shoe approach (10.33).

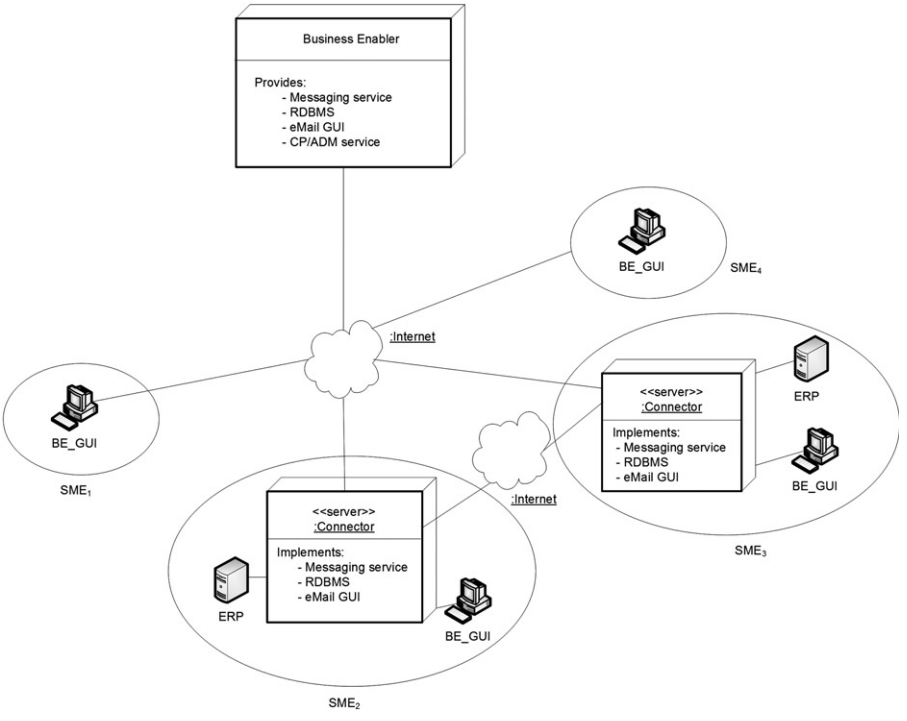

Figure 2. System architecture (UML) (adapted from Chituc *et al.* 2009).

For the textile/clothing industry, for weights assigned to individual criteria (Formula (1)), the maximum value for the interoperability characterisation function has been obtained for ebXML (65), followed by CIbFw (51.98). The lowest value has been obtained for TexWeav approach (37.31). The standard deviation is 13.85, and the coefficient of variation is 26.92%, which reflects data homogeneity. For weights assigned to groups of criteria, the highest score has been obtained for ebXML (25), followed closely by CIbFw (24.66) (Table 3). The lowest score has been obtained for TexWeave approach (10.33).

However, the results have to be interpreted with care since they are specific to the numerical values and weights assigned by the TECMODA project coordinator, which have a degree of subjectivity. Besides, it is important to consider the results obtained for groups of criteria. For example, although the overall score for the interoperability characterisation function is higher for ebXML than for CIbFw for both the footwear and textile/clothing industries, higher scores have been obtained for CIbFw for a certain group of criteria, e.g., performance assessment. Also, since ebXML is a much more mature initiative, the values for the criteria related to specifications (e.g., C18 – maturity) and implementations (e.g., C21 – tools support, C22 – ICT platforms) are normally higher. Additionally, it is important to emphasise that CIbFw follows relatively close the ebXML specifications.

4.2.3 *Results by using the Analytic Hierarchy Process multi-criteria method*

Two situations are presented below: the AHP considering seven groups of criteria, and the AHP considering all 22 criteria described in Section 3.1 and Table 1. The results reflect the

Table 2. Results for the interoperability characterisation function considering the weights assigned to individual criteria and groups of criteria (TECMODA project).

Criterion/group of criteria	Footwear industry						Textile industry					
	w_i	CIbFw	ebXML	CEC-made -shoe	Mean value	Standard deviation	w_i	CIbFw	ebXML	TexWeave	Mean value	Standard deviation
(G1) Description and publication	**5**	**5**	**5**	**0**	**3.33**	**2.88**	**5**	**5**	**5**	**5**	**5**	**0**
C1 Description	5	5	5	0			5	5	5	5		
C2 Publication	5	5	5	0			5	5	5	0		
(G2) Search	**4**	**4**	**4**	**0**	**2.66**	**2.3**	**5**	**5**	**5**	**0**	**3.33**	**2.88**
C3 Identification of potential business partner/opportunity	4	4	4	0			5	5	5	0		
(G3) Collaboration	**4**	**4**	**4**	**4**	**4**	**0**	**4**	**4**	**4**	**4**	**4**	**0**
C4 Messaging	4	4	4	4			4	4	4	4		
C5 Inter-organisational collaborations	3	3	3	3			3	3	3	3		
C6 Negotiation and agreements	3	3	3	0			3	3	3	3		
C7 Semantics	4	4	4	2			4	4	4	2		
(G4) Management	**4**	**4**	**4**	**4**	**4**	**0**	**4**	**4**	**4**	**4**	**4**	**0**
C8 Information management	5	5	5	5			5	5	5	5		
C9 Conflict solving	3	3	0	0			3	3	0	0		
C10 Rights and obligations	3	3	0	0			3	3	0	0		
C11 Roles/tasks fulfilment	4	0	0	0			4	0	0	0		
C12 Learning	2	0	0	0			2	0	0	0		
(G5) Performance assessment	**3**	**3**	**0**	**0**	**1**	**1.73**	**3**	**3**	**0**	**0**	**1**	**1.73**
C13 Performance assessment	3	3	0	0			3	3	0	0		
(G6) Specifications	**4**	**2.66**	**4**	**1.33**	**2**	**1.33**	**4**	**2.66**	**4**	**1.33**	**2**	**1.33**
C14 Technical specifications	3	1	3	1			3	1	3	1		
C15 Comprehensibility	4	4	4	2.66			4	4	4	2.66		
C16 Generality	2	1.33	2	0.33			2	1.33	2	1.33		
C17 Targeted enterprise (by size)	4	2.66	4	2.66			5	3.33	5	3.33		
C18 Maturity[1]	3	0.66	3	1			3	0.66	3	1		
C19 Policy	4	2.66	4	2.66			4	2.66	4	1.33		
C20 Accessibility	4	4	4	2.66			4	4	4	2.66		
(G7) Implementations	**3**	**1**	**3**	**1**	**1.66**	**1.15**	**3**	**1**	**3**	**1**	**1.66**	**1.15**
C21 Tools support	3	1	3	1			3	1	3	1		
C22 ICT platforms	3	1	3	1			3	1	3	1		
Interoperability characterisation function		**60.31**	**63**	**28.97**	**50.76**	**18.91**		**51.98**	**65**	**37.31**	**51.43**	**13.85**

Note: [1]Number of years since the first specification has been published: ebXML (1999) – 9 years, CIbFw (2006) – 2 years, CEC-made-shoe (2005)–3 years, TexWeave (2005) – 3 years (calculations performed during 2008).

pairwise comparisons of criteria and approaches for the SMEs in the footwear and textile/clothing industry based on the data collected from the TECMODA ICT platform development project coordinator. The goal is to characterise/analyse/better understand each initiative, and to emphasise their strengths and weaknesses, and not to promote an approach over the others.

(1) AHP in assisting e-business frameworks analysis based on seven groups of criteria

The weights (w_i) for the pairwise comparison matrix for the seven groups of criteria have been calculated based on the geometric means method. Table 3 presents the priorities obtained for the three alternatives, for the three linear additive functions, in which the relative priorities for an alternative are multiplied by the relative importance of the corresponding criterion and summed over all criteria. The results obtained illustrate that ebXML should be selected as the most appropriate collaborative e-business framework, followed by the CIbFw, and CEC-made-shoe/TexWeave approaches.

(2) AHP in assisting e-business frameworks analysis based on 22 criteria

Pairwise comparisons for the 22 criteria have been elaborated. The corresponding weights (w_i) are calculated based on the geometric means method. Table 4 presents the priorities obtained for the three alternatives, for the three linear additive functions, in which the relative priorities for an alternative are multiplied by the relative importance of the corresponding criterion and summed over all criteria. The highest score has been obtained for ebXML, which may indicate that ebXML should be selected as the most appropriate collaborative e-business framework, followed by the CIbFw, CEC-made-shoe and TexWeave/MODA-ML approaches.

5. Discussion

Research aiming at analysing and comparing e-business frameworks is challenging. The challenges are related to the difficulty to trace the adoption of these initiatives, frequent changes on the specifications of a certain e-business framework, the disappearance of a certain initiative, and the emergence of new approaches.

As emphasised by Shapiro and Varian (1998), a trade-off between performance and compatibility always exists in the context of e-business frameworks. The authors have argued that large frameworks have advantages over small networks in adoption. This means that although several e-business frameworks may coexist in a certain moment, only a few survive in the long term. Also, a generic e-business framework can be expected to

Table 3. Final priorities related to each alternative for seven groups of criteria (TECMODA project).

	CIbFw	ebXML	CEC/TexWeave
Criterion 1 (0.14)	0.3	0.62	0.08
Criterion 2 (0.22)I	0.45	0.45	0.1
Criterion 3 (0.22)	0.45	0.45	0.1
Criterion 4 (0.15)	0.69	0.23	0.08
Criterion 5 (0.03)	0.2	0.2	0.6
Criterion 6 (0.13)	0.59	0.13	0.28
Criterion 7 (0.11)	0.14	0.72	0.14
Priority	**0.3721**	**0.4214**	**0.137**

have more potential users than a vertical framework. However, other elements have to be considered as well, e.g., the number of inter-organisational interactions; the number of different industries with which a certain organisation collaborates. Therefore, the specification and development of only one e-business framework is not always the most desired solution.

According to Nurmilaakso *et al*. (2006) the analysis performed on different e-business frameworks allowed the identification of several commonalities and differences in their properties, the identification of the characteristics on which they complete and/or complement each other.

The messaging element is stabilising; most frameworks use ebMS or RNIF. In fact, RosettaNet intends to support ebMS. A high variety of business documents exist, which are in continuous evolution. The specifications of the inter-organisational collaborations are evolving as well (Nurmilaakso *et al*. 2006).

CIbFw vs ebXML: the CIbFw and ebXML present several similarities and differences (Chituc *et al*. 2009). They both comprise messaging and repository elements, and the communication is message/document oriented. Like ebXML framework, CIbFw refers to organisations' *collaboration profile* (CP) and *collaboration agreement* (CA), which are stored in the repository as documents. The *collaboration profile*, as in ebXML, describes the capabilities of an individual organisation. However, unlike ebXML which encourages the existence of several CPs for an organisation (e.g., a CP to describe each role or business collaboration supported, or its operations in different regions of the world), the CIbFw proposes an approach where each organisation has one and only one CP. From an

Table 4. Final priorities related to each alternative for 22 criteria (TECMODA project).

	CIbFw	ebXML	CEC/TexWeave
C1 (0.011)	0.62	0.3	0.08
C2 (0.026)	0.45	0.45	0.1
C3 (0.076)	0.26	0.64	0.1
C4 (0.117)	0.34	0.33	0.34
C5 (0.1)	0.43	0.43	0.14
C6 (0.107)	0.45	0.45	0.1
C7 (0.031)	0.34	0.33	0.33
C8 (0.072)	0.64	0.1	0.26
C9 (0.014)	0.6	0.2	0.2
C10 (0.013)	0.43	0.43	0.14
C11 (0.012)	0.43	0.43	0.14
C12 (0.024)	0.34	0.33	0.33
C13 (0.017)	0.2	0.2	0.6
C14 (0.033)	0.14	0.72	0.14
C15 (0.055)	0.2	0.2	0.6
C16 (0.036)	0.26	0.64	0.1
C17 (0.055)	0.43	0.14	0.43
C18 (0.04)	0.14	0.72	0.14
C19 (0.022)	0.34	0.33	0.33
C20 (0.039)	0.2	0.6	0.2
C21 (0.05)	0.14	0.72	0.14
C22 (0.05)	0.2	0.6	0.2
Priority	**0.343**	**0.426**	**0.231**

implementation point of view, this approach is more practical, and avoids the storing of redundant information. A *performance_history* section to be included in the CP is proposed in CIbFw, where the result of the evaluation of a former e-business partner is saved, as described by Chituc (2008).

The *collaboration agreement*, as in ebXML, describes the capabilities two organisations have agreed to use to perform e-business. However, for the CIbFw in case the organisations perform e-business through the messaging service provided by the Business Enabler's system, the CA document does not include technical details on the two organisations (e.g., communication protocols used). According to ebXML scenario, the CA is negotiated by two SMEs by directly exchanging different versions of the CA document. According to the CIbFw, the organisations negotiate by uploading to the centralised repository different versions of intermediate CA documents. The Business Enabler's system signs the final CA document, which may be downloaded by SMEs from the centralised repository.

Main differences between the CIbFw and ebXML are: the CIbFw supports two types of communication over the Internet (through the messaging service provided by the business enabler's system, or directly on a peer-to-peer basis); the CA document contains details on the business (e.g., delivery date, products or models sold), and may not refer technical details; the CP document contains a *performance_history* field, which represents an organisation's evaluation made by a former e-business partner; the specification of a set of five clusters for inter-organisational collaborations; the specification of the performance assessment service, which tackles business/economic interoperability issues; the CIbFw addresses aspects related to collaborative networks' management and conflict solving.

However, the main difference is generated by the existence of the Business Enabler entity, which provides different services to the organisations in the community: messaging, CP/ADM, and performance assessment.

CIbFw vs CEC-made-shoe approach: CEC-made-shoe approach is using a proprietary messaging platform not compliant with ebMS, and needs further work to integrate the two operational infrastructures. It does not address aspects related to the automation of collaboration agreements setting and it does not tackle business/economic interoperability aspects, which are of relevance for this industry sector, and are addressed only by CIbFw.

CIbFw vs TexWeave/Moda-ML initiatives: TexWeave/Moda-ML initiatives make use of ebMS, and have also adopted ebXML BPSS and Collaboration Protocol Profile documents. However, unlike in CIbFw, the communication is only on peer-to-peer basis. Business/economic interoperability aspects are not addressed by TexWeave/Moda-ML initiatives.

The CIbFw covers the main views on interoperability: technical, information/knowledge, and business/economic. In fact, CIbFw is the only framework addressing business/economic interoperability aspects.

TECMODA R&D project ICT platform coordinator has indicated that for the footwear and textile/clothing industries the technical and business/economic interoperability aspects are essential, followed by knowledge/semantic interoperability issues (which have been indicated as very important).

Concerning the analytical approaches to compare e-business frameworks, they may be useful to characterise and understand an e-business framework, emphasising its strengths and weaknesses. Although the analytical comparisons have not been aimed at recommending an initiative over others, the results obtained showed that the proposed methods may

support a decision maker in the e-business frameworks selection process since these methods indicate that a certain e-business framework fits best certain requirements or criteria.

The analytical comparison performed showed a slight advantage of ebXML over CIbFw, RosettaNet and papiNet, when the values of the weights assigned to each criteria were equal (Table 1). Simulations made with different values assigned to the weights associated to criteria or groups of criteria showed that the value of the interoperability characterisation function may be higher for CIbFw (e.g., for cases when higher weights are associated to management and performance assessment criteria). However, these results have to be interpreted with care since the values obtained for the interoperability characterisation function are specific to the numerical values associated.

Real data has been collected from the TECMODA R&D ICT platform project coordinator, which has been used to calculate the interoperability characterisation function and to apply the AHP method to analyse industry-neutral (e.g., ebXML, CIbFw) and industry specific initiatives (e.g., CEC-made-shoe approach for the footwear industry, and TexWeave/Moda-ML initiatives for the textile/clothing industry). One of the main difficulties has been the impossibility to make a clear distinction between weights assigned to criteria or groups of criteria for the SMEs in the footwear and textile/clothing industry. This also stands for the criteria pairwise comparisons.

The appropriateness of the AHP multi-criteria decision method to support e-business framework selection has been explored. The examples illustrated revealed that the AHP may be useful for a decision maker to select a framework, based on the criteria proposed. However, this method has strengths and weaknesses, and the results have to be interpreted with care. For example, the number of pairwise comparisons a decision maker has to make may increase quickly when a large number of criteria, sub-criteria and alternatives are considered. Also, the assumption of the independence of criteria may cause problems in practice.

However, the results obtained have illustrated the applicability and usefulness for decision makers of the interoperability characterisation function and AHP methods in e-business frameworks analysis, characterisation and selection. The decision maker should have a solid knowledge on the e-business frameworks to be analysed or compared, and organisation/industry requirements. A good understanding of the comparison criteria and analytic methods is required, and no knowledge is necessary on how the calculations are performed (e.g., a software package may be used to make the calculations).

6. Conclusions and future research work

Economic factors, market determinants and technology advancements have determined organisations to engage in new organisational structures, such as collaborative networks (CNs). CNs enable disparate organisations to share and use resources in a controlled fashion in order to achieve a common objective. They require adequate e-business frameworks and ICT platforms to attain the goals set.

Although intensive research is being pursued focusing on e-business frameworks, few studies aim at comparing e-business frameworks. The few existing studies, e.g., Shapiro and Varian (1998), Jakobs (2002), and Nurmilaakso *et al.* (2006), are rather descriptive than comparative. Studies on e-business frameworks analytic comparison are scarce.

The research work pursued allowed the identification of a set of 22 comparison criteria and the definition of an interoperability characterisation function which allow e-business frameworks analytic comparison. The applicability of the Analytic Hierarchy Process (AHP) multi-criteria method in e-business frameworks selection has also been analysed. The usefulness of both methods has been tested with real data collected from the ICT platform development project coordinator of TECMODA R&D project targeting the footwear, and textile/clothing industries.

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

(1) Which are the most relevant industry-neutral and industry-specific e-business frameworks currently in use?

Relevant industry-neutral and industry-specific e-business frameworks have been presented in Section 2: ebXML, CIbFw and ATHENA interoperability framework as industry-neutral initiatives, and TexWeave/Moda-ML and ShoeBiz as industry-specific initiatives. A more detailed comparison of industry-neutral and industry-specific initiatives is available in Chituc *et al.* (2008b).

(2) How can e-business frameworks be compared?

Different characteristics for comparing e-business frameworks have been presented by Shapiro and Varian (1998), Jakobs (2002), Medjahed *et al.* (2003), Nurmilaakso and Kotinurmi (2004), and Nurmilaakso *et al.* (2006), and they concern: properties of e-business frameworks (e.g., business documents, inter-organisational collaborations, and messaging), or standardisation: industry, openness, drivers, organisations. However, these criteria allow a more descriptive analysis of the frameworks.

The criteria to be used to compare conceptual frameworks should address a broad view on interoperability and general requirements for interoperability, e.g., the main views on interoperability should be considered simultaneously. However, the definition of the criteria should be made considering the objective of the comparison. A manager, decision maker or stakeholder may assign a different importance to each individual criterion. Thus, an analytical comparison is more appropriate, where weights are associated to each criterion (or to groups of criteria).

Twenty-two criteria (which have been congregated in seven groups of criteria to support an analytical comparison have been proposed in Section 3.1 and described in Table 1): description; publication; identification of potential business partner/opportunity; messaging; inter-organisational collaborations; negotiation and agreements; semantics; information management; conflict solving; rights and obligations; roles/tasks fulfilment; learning capacity; performance assessment; technical specifications; comprehensibility; generality; targeted enterprises (by size); maturity; policy; accessibility; tools support; and ICT platforms. The definition of these criteria has been elaborated considering the main requirements for interoperability identified and the gap analysis presented by Chituc (2008), and Chituc *et al.* (2008b).

An interoperability characterisation function has also been defined (Section 3.2). The results obtained by using this comparison method have to be interpreted with care, since a certain criterion may be dependent on other, and a group of criteria may be more technical than others. However, such an analytical approach emphasises the strengths and weaknesses of the e-business frameworks compared, helping managers, decision makers or stakeholders to determine which framework fits their requirements.

The applicability of the Analytic Hierarchy Process multi-criteria decision method to compare e-business frameworks has been illustrated in Section 4 (based on the criteria

proposed in Section 3.1). This method may be useful for decision makers in supporting them to select an e-business framework.

(3) Do e-business frameworks compete or complement each other?

The analysis of the e-business frameworks illustrated that the e-business frameworks compete in some aspects, while they complement each other, supporting the conclusions presented by Nurmilaakso *et al*. (2006): they compete on aspects which may be substitutes (e.g., business documents), and complement each other, for example for messaging: ebXML's messaging service ebMS complements papiNet.

However, competition may be more intensive on some aspects: competition between e-business frameworks is higher with respect to business documents than on messaging, which shows that the messaging is becoming more stable. Concerning business processes, their specifications evolve fast. These results are in line with the remarks presented by Nurmilaakso *et al*. (2006).

The e-business frameworks following a generic approach (e.g., for business documents, or inter-organisational collaborations, such as ebXML or CIbFw) usually represent complements to other frameworks. Most e-business frameworks provide specifications for business documents, overlapping each other. However, this overlapping is partial, because industry-specific approaches specify more in detail business documents and inter-organisational collaborations. Thus, inter-organisational collaborations/business processes represent weak substitutes to each other, e.g., RosettaNet and papiNet (Nurmilaakso *et al*. 2006). This is due to the fact that vertical approaches are built to answer the specificities and needs of a certain industry, and make use of a specific dictionary or vocabulary. However, most of the industry-specific initiatives are at their infancy and require further developments.

Competition among e-business frameworks is strong for the support of potential adopters, e.g., Nurmilaakso *et al*. (2006). For the e-business frameworks which provide generic approaches to business documents, inter-organisational business processes or messaging, the use of XML is of special interest.

(4) Which are the main differences and similarities between existing e-business frameworks?

The main difference between the CIbFw and other frameworks is the existence of the Business Enabler entity, which has different functions (e.g., to solve potential conflicts). The Business Enabler's system provides various services to the organisations in a community, e.g., messaging service, performance assessment. The CIbFw allows organisations to communicate directly or through the messaging service provided by the Business Enabler's system.

The specifications of industry-specific e-business frameworks are more detailed than in the case of cross-industry frameworks. As emphasised by Nurmilaakso *et al*. (2006), users tend to drive standardisation of industry specific initiatives, and vendors for cross-industry approaches.

The results of the analytical comparison (Section 4) elaborated based on the 22 criteria defined showed a slight advantage of ebXML over CIbFw, CEC-made-shoe and TexWeave approaches, considering their support for seamless interoperability in a CNE. The CIbFw is the only approach addressing the main views on interoperability (technical, information and business/economic), which better covers all CN phases, and CN management and performance assessment issues. However, ebXML is a more mature initiative and has a higher number of implementations following its specifications.

(5) Which criteria and or method(s) may be used to support a decision maker or developer in selecting an e-business framework?

The 22 criteria and the interoperability characterisation function, and the AHP multi-criteria method may be used to support decision makers or developers in selecting an e-business framework. They allow a better characterisation and understanding of an e-business framework, emphasising its strengths and weaknesses. However, the numerical values have to be interpreted with care.

In order to use these methods, a decision maker should have a good knowledge of the e-business frameworks specifications, general and/or industry-specific requirements and comparison criteria and their scale definition, and to know how to use these methods (and not how to calculate the results).

Future research will focus on critical factors for e-business frameworks (e.g., critical factors for the adoption and success in standardisation), and the analysis of the impact the adoption of e-business frameworks has on organisations' or CNs' performance.

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Notes

1. The concept of seamless interoperability in a collaborative networked environment – as presented by Chituc *et al.* (2008b, 2009) – 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 organisations. The aim is to achieve added value by attaining a set of objectives, while the systems are added and/or removed without requiring reconfiguration, and an organisation, CN or sub-CN's decision to join, leave or remain in a CN or community is based on an economic analysis. Thus, seamless interoperability in a CNE addresses technical, knowledge and business/economic aspects.
2. These initiatives and e-business frameworks presented in the following subsections have been selected because they are potentially the most relevant towards seamless interoperability in a CNE and cover industry-specific and industry-neutral frameworks.
3. Where i is from 1 to 22.
4. In case $\max(Ci(F_j)) = 0$, criterion Ci will not be considered.
5. These e-business frameworks have been selected for comparison because they are potentially the most relevant towards seamless interoperability in a CNE, and cover industry-specific and industry-neutral frameworks.
6. The mean value represents the arithmetic mean. It is often used to report central tendency.
7. The standard deviation is a measure of how widely values are dispersed from the mean value.
8. The coefficient of variation (CV) has been calculated by using the formula: $CV = (\sigma/\mu)*100\%$, 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.
9. A detailed analysis of the applicability of the AHP multi-criteria method for e-business frameworks selection is available in Chituc (2008).
10. A complete description of the Business Enabler entity, its role and responsibilities and the tasks performed by the Business Enabler's system are available in Chituc (2008).
11. The values associated to the weights are between 0 and 5, as follows: 0 – it does not apply; 1 – very little importance; 2 – little importance; 3 – important; 4 – very important; 5 – essential.

References

Abreu, A. and Camarinha-Matos, L.M., 2008. On the role of value systems to promote sustainability of collaborative environments. *International Journal of Production Research*, 46 (5), 1207–1229.

Akhavi, F. and Hayes, C., 2003. A comparison of two multi-criteria decision making techniques. *In*: *Proceedings of IEEE international conference on systems*, *man and cybernetics*, Vol. 1, 5–8 October, Washington DC, USA. IEEE, 956–961.

ATHENA, Advanced Technologies for Interoperability of Heterogeneous Enterprise Networks and their Applications, IST-507849 European Integrated Project, 2007 [online]. Available from: www.athena-ip.org [Accessed on 20-10-2008].

Bernauer, M., Kappel, G., and Kramler, G., 2003. Comparing WSDL-based and ebXML-based approaches for B2B protocol specification. *In*: *Proceedings of ICSOC 2003*, 15–18 December, Trento, Italy. Springer-Verlag, LNCS 2910/2003, 225–240.

BPEL4WS, Business Process Execution Language for Web Services, 2002 [online]. Available from: www.ibm.com/developerworks/library/ws-bpel [Accessed on 20-10-2008].

BPML, Business Process Modeling Language, 2008 [online]. Available from: www.ebpml.org/bpml.htm [Accessed on 20-10-2008].

Buede, D.M., 1993. Software review: three packages for AHP: Criterium, ExpertChoice and HIPRE3 + . *Journal of Multi-Criteria Decision Analysis*, 1 (2), 119–21.

Bussler, C., 2003. *B2B Integration – concepts and architectures*. New York: Springer.

Camarinha-Matos, L.M. and Afsarmanesh, H., 2003. Elements of a VE base infrastructure. *Computers in Industry*, 51 (2), 139–163.

Camarinha-Matos, L.M. and Afsarmanesh, H., 2008. On reference models for collaborative networked organizations. *International Journal of Production Research*, 46 (9), 2453–2469.

CEC-made-shoe Custom, Environment and Comfort made shoe, IST-NMP 507378 European project, 2004-2008 [online]. Available from: www.cec-made-shoe.com [Accessed on 20-10-2008].

Chituc, C.-M. and Azevedo, A., 2006. Business networking – the technological infrastructure support, *In*: M. Cunha and G. Putnik, eds. *Knowledge and technology management in virtual organizations*. Hershey, PA: Idea Group Publishing, 334–354, (chapter 16).

Chituc, C.-M. and Nof, S.Y., 2007. The join/leave/remain (JLR) decision in collaborative networked organizations. *Computers and Industrial Engineering*, 53 (1), 173–195.

Chituc, C.-M., Toscano, C., and Azevedo, A., 2007. E-business and collaborative networks: a service-oriented architecture for the footwear industry. *In*: *Proceedings of IEEE SCC 2007*, 9–13 July, Salt Lake City, USA, 451–457.

Chituc, C.-M., 2008. *Interoperability in collaborative networks*: *a framework proposal*. Thesis (PhD). Faculty of Engineering, University of Porto, Portugal.

Chituc, C.-M., Azevedo, A., and Toscano, C., 2008a. An analytical approach for comparing e-business frameworks. *In*: A. Azevedo, ed. *Innovation in* Manufacturing Net*works*. London: Springer, 137–144. [*From*: 8*th IFIP international conference on information technology for balanced automation systems* (*BASYS*)].

Chituc, C.-M., Toscano, C., and Azevedo, A., 2008b. Interoperability in collaborative networks: independent and industry-specific initiatives – the case of the footwear industry. *Computers in Industry*, 59 (7), 741–757.

Chituc, C.-M., Azevedo, A., and Toscano, C., 2009. A framework proposal for seamless interoperability in a collaborative networked environment. *Computers in Industry*, 60(5), 317–338.

Davidow, W.H. and Malone, M.S., 1992. *The virtual corporation*. New York: Harper Collins.

Davis, L. and Williams, G., 1994. Evaluating and selecting simulation software using the analytic hierarchy process. *Integrated Manufacturing Systems*, 5 (1), 23–32.

Dogac, A. and Cingil, I., 2001. A survey and comparison of business-to-business e-commerce frameworks. *ACM SIGecom Exchanges*, 2 (2), 14–25.

ebXML, Electronic Business using eXtensible Markup Language, 2008 [online]. Available from: www.ebxml.org [Accessed on 20-10-2008].

ECOLEAD, European Collaborative Networked Organizations Leadership Initiative, FP6-IST 506958 European Integrated Project, 2004-2008 [online]. Available from: http://ecolead.vtt.fi [Accessed on 20-10-2008].

EDIINT-AS2, EDI over the Internet Applicability Statement 2 [online]. Available from: http://www.ediuniversity.com/intermediate/as2.jsp [Accessed on 20-10-2008].

Farrell, J. and Saloner, G., 1988. Coordination through committees and markets. *RAND Journal of Economics*, 19 (2), 235–252.

Frazelle, E., 1985. Suggested techniques enable multi-criteria evaluation of material handling alternatives. *Industrial Engineering*, 17 (2), 42–48.

Hasselbering, W. and Weigand, H., 2001. Languages for electronic business communication: state of the art. *Industrial Management and Data Systems*, 101 (5), 207–216.

HERMES H2O Messaging Gateway Open Source Version, 2008 [online]. Available from: http://www.freebxml.org/msh.htm [Accessed on 20-10-2008].

Hinge, K.C., 1998. *Electronic data interchange: from understanding to implementation*. New York: AMA Membership Publications Division.

Huang, C.-Y. and Wu, Y.-W., 2003. Decision model for partnership development in virtual enterprises. *International Journal of Production Research*, 41 (9), 1855–1872.

IDEAS Roadmap for eBusinessInteroperability, IST-2001-37368 European Project, 2002-2003 [online]. Available from: www.ideas-roadmap.net [Accessed on 20-10-2008].

Jakobs, K., Procter, R., and Williams, R., 1998. User participation in standards setting – the panacea? *ACM Standards View*, 6 (2), 85–89.

Jakobs, K., 2002. A proposal for alternative standards setting process. *IEEE Communication Magazine*, 40 (7), 118–123.

Katz, M.L. and Shapiro, C., 1985. Network externalities, competition and compatibility. *American Economic Review*, 75 (3), 424–440.

Kim, D.J., *et al*., 2003. A comparison of B2B e-service solutions. *Communications of ACM*, 46 (12), 317–324.

Kong, F. and Liu, H., 2005. Applying fuzzy analytic hierarchy process to evaluate success factors for e-commerce. *International Journal of Information and Systems Science*, 1 (3–4), 406–412.

LEAPFROG, Leadership for European Apparel Production From Research along Original Guidelines, European Integrated Project, 2005-2009 [online]. Available from: www.leapfrog-eu.org [Accessed on 20-10-2008].

Li, H., 2000. XML and industrial standards for electronic commerce. *Knowledge and Information Systems*, 2 (4), 487–497.

Li, H., Lu, M., and Li, O., 2006. Software reliability metrics selecting method based on analytic hierarchy process. *In*: *Proceedings of IEEE QSIC 2006*, 26–28 October, Beijing, China, 337–346.

Medjahed, B., *et al*., 2003. Business-to-business interactions: issues and emerging technologies. *VLDB Journal*, 12 (1), 59–85.

Mendoza, R.A. and Ravichandran, T., 2007. Organizational assimilation of vertical standards: an integrative model. *In*: *Proceedings of IEEE HICSS 2007*, 3–6 January, Hawaii, USA, 173b–173b.

Moda-ML, Middleware tOols and Documents to enhAnce the textile/clothing supply chain through xML, 2008 [online]. Available from: www.moda-ml.org [Accessed on 20-10-2008].

Mohanty, R.P. and Venkataraman, S., 1995. Use of the analytic hierarchy process for selecting automated manufacturing systems. *International Journal of Operations and Production Management*, 13 (8), 45–57.

Molina, A., Velandia, M., and Galeano, N., 2007. Virtual enterprise brokerage: a structure-driven strategy to achieve build to order supply chains. *International Journal of Production Research*, 45 (17), 3853–3880.

Mykkanen, J.A. and Toumainen, M.P., 2008. An evaluation and selection framework for interoperability standards. *Information and Software Technology*, 50 (3), 176–197.

Nurmilaakso, J.M. and Kotinurmi, P., 2004. A review of XML-based supply-chain integration. *Production Planning and Control*, 15 (6), 608–621.

Nurmilaakso, J.-M., Kotinurmi, P., and Laesvuori, H., 2006. XML-based e-business frameworks and standardization. *Computer Standards & Interfaces*, 28 (5), 585–599.

Nurmilaakso, J.-M., 2008a. Adoption of e-business functions and migration from EDI-based to XML-based e-business frameworks in supply chain integration. *International Journal of Production Economics*, 113 (2), 721–733.

Nurmilaakso, J.-M., 2008b. EDI, XML and e-business frameworks: a survey. *Computers in Industry*, 59 (4), 370–379.

Pollock, J.T., 2001. The biggest issue: interoperability vs. integration. *eAI Journal*, October (8), 48–52.

Pusnik, M. and Juric, M.B., 2002. Comparison of technologies for connecting business processes among enterprises. *Information Society IS*, 21–24.

Pusnik, M., Juric, M.B., and Rozman, I., 2002. Evaluation of technologies for business process automation. *Informatica* (Slovenia), 26 (4), 373–380.

Pusnik M., *et al*., 2003a. *A comparison of ebXML and RosettaNet*. Available from: http://www.mipro.hr/savjetovanja/DE03.pdf [Accessed 20 October 2008].

Pusnik, M., *et al*., 2003b. Business process orchestration and ebusiness. *In*: *Proceedings of 16th Bled eCommerce conference*, 9–11 June, Bled, Slovenia.

Rangone, A., 1996. An analytical hierarchy process framework for comparing the overall performance of manufacturing departments. *International Journal of Operations and Production Management*, 16 (8), 104–119.

Saaty, T.L., 1980. *The analytic hierarchy process*. New York: McGraw-Hill.

Saaty, T.L., 1987. Rank generation, preservation, and reversal in the analytic hierarchy process. *Decision Sciences*, 18 (2), 157–177.

Saaty, T.L., 1997. Highlights and critical points in the theory and application of analytic hierarchy process. *European Journal of Operational Research*, 74 (3), 426–447.

SCI, Web Service Choreography Interface, 2002 [online]. Available from: www.w3.org/TR/wsci [Accessed on 20-10-2008].

Shapiro, C. and Varian, H.R., 1998. *Information rules – a strategic guide to the network economy*. Boston, MA: Harvard Business School Press.

Shim, S., *et al*., 2000. Business-to-business e-commerce frameworks. *IEEE Computer*, 33 (10), 40–47.

ShoeBiz, Portuguese project, 2006 [online]. Available from: http://svr-shoebiz.ctcp.pt [Accessed on 20-10-2008].

SHOENET, Shoe Information Network, 2008 [online]. Available from: www.shoenet.info [Accessed on 20-10-2008].

Sloane, E.B., Liberatore, M.J., and Nydick, R.L., 2002. Medical decision support using the analytic hierarchy process. *Journal of Healthcare Information Management*, 1 (4), 38–43.

SOAP, Simple Object Access Protocol, 2000 [online]. Available from: http://www.w3.org/TR/soap/ [Accessed on 20-10-2008].

Stanescu, A.M., *et al*., 2002. Supervisory control and data acquisition for virtual enterprises. *International Journal of Production Research*, 40 (15), 3545–3559.

TECMODA, Centro de Excelência da Moda, Portuguese Project 162/7.1/ADI/C/NOR, 2006-2008 [online]. Available from: www.tecmoda.org [Accessed on 20-10-2008].

TEXWEAVE, Standardisation and Interoperability in the Textile Supply Chain Integrated Networks, CEN/ISSS standardization Workshop, 2005-2006 [online]. Available from: www.texweave.org [Accessed on 20-10-2008].

Tsai, C.-Y., Tien, F.-C., and Pan, T.-Y., 2004. Development of an XML-based structural product retrieval system for virtual enterprises. *International Journal of Production Research*, 42 (8), 1505–1524.

Wabalickis, R.N., 1988. Justifications of FMS with the analytic hierarchy process. *Journal of Manufacturing Systems*, 7 (3), 175–182.

WSCI, Web Service Choreography Interface, 2002 [online]. Available from: www.w3.org/TR/wsci [Accessed on 20-10-2008].

WSDL, Web Services Description Language, 2001 [online]. Available from: www.w3.org/TR/wsdl [Accessed on 20-10-2008].

WSFL, Web Services Flow Language [online]. Available from: www.wsfl.org [Accessed on 20-10-2008].

XLANG, 2008 [online]. Available from: www.ebpml.org/xlang.htm [Accessed on 20-10-2008].

XML, Extensible Markup Language, 1998 [online]. Available from: http://www.w3.org/XML/ [Accessed on 20-10-2008].

XSD, XML Schema, 2001 [online]. Available from: http://www.w3.org/XML/Schema [Accessed on 20-10-2008].

Zhao, K., Xia, M., and Shaw, M., 2005. Vertical e-business standards and standards developing organizations: a conceptual framework. *Electronic Markets*, 15 (4), 289–300.

Zhao, Y. and Sandhal, K., 2000. XML-based frameworks for Internet commerce. *In*: *Proceedings of the international conference on enterprise information systems*, 5–7 July, Stafford, UK, 511–516.

Appendix 1. The Analytic Hierarchy Process: a brief overview

The Analytic Hierarchy Process (AHP) (Saaty 1980, 1987, 1997) is a multi-criteria decision making method, which uses hierarchic or network structures to represent a decision problem (Figure A1). Pairwise comparisons of decision elements (either criteria or alternatives) are performed in order to arrive at priority scores of the elements considered.

Let us denote with A the set of alternatives: $A = \{A_1, A_2, \ldots, A_n\}$, where n is the number of alternatives, their actual weights are $\{w_1, w_2, \ldots, w_n\}$, and the matrix of all ratios of all weights by $W = [w_i/w_j]$. The matrix of pairwise comparisons $A_c = [a_{ij}]$ represents the intensities of the decision maker's preference between individual pairs of alternatives (e.g., A_i versus A_j for all $1 \leq i, j \leq n$). The relative importance of two elements can be scored by a decision maker on a nine point interval-valued scale (which is illustrated in Table A1).

For a set of n alternatives, the decision maker compares a pair of alternatives for all possible pairs, $n^*(n-1)/2$, then the comparison matrix A_c is obtained, where its element a_{ij} shows the preference weight of A_i obtained by comparing it with A_j.

The elements a_{ij} are considered to be estimates of the ratios w_i/w_j, where w is the vector of actual weights of the alternatives. The ratios are positive and satisfy the reciprocity property: $a_{ij} = 1/a_{ji}$, $\forall\, i, j$, $1 \leq i, j \leq n$.

From a theoretical point of view, the AHP is based on the following four axioms (Saaty 1980, 1987, 1997):

(1) The decision maker can provide paired comparison of two alternatives corresponding to a criterion/sub-criterion on a ratio scale that is reciprocal.
(2) The decision maker never judges one alternative to be infinitely better than another corresponding to a criterion.
(3) The decision problem can be formulated as a hierarchy.
(4) All criteria/sub-criteria that have some impact on the given problem and all the relative alternatives are represented in the hierarchy in one go.

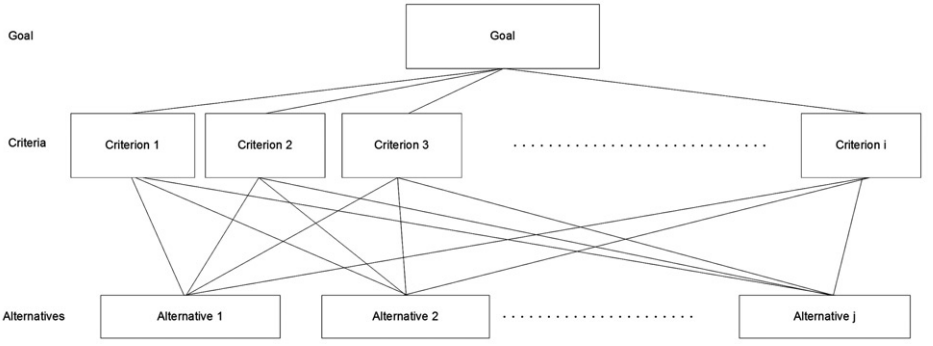

Figure A1. Example of decision hierarchy for the AHP for *i* criteria and *j* alternatives (adapted from Saaty 1980, 1987, 1997).

Table A1. Scale of relative importance of two elements for the AHP (Saaty 1980, 1987, 1997).

Value	Interpretation
1	A_i and A_j are of equal importance
3	A_i is weakly more important than A_j
5	A_i is strongly more important than A_j
7	A_i is very strongly or demonstrably more important than A_j
9	A_i is absolutely more important than A_j
2, 4, 6, 8	Intermediate values