Concept and development of an evolutionary platform for collaborative engineering work

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Abstract: This paper presents an evolutionary concept developed as part of a specific collaborative engineering platform to support the commercialization of engineering services. This concept establishes a pattern for continuously adapting the platform to a variety of situations and specific user needs, product characteristics and industrial sectors. The AEC and Mechanical sectors were chosen for the initial focus of the platform. Based on three real cases of collaboration in these industrial sectors, the development of the concept is underpinned by a reference business process and workflow technologies. This paper discusses the concept and presents the initial portfolio of collaborative workflows. The platform has been implemented and tested.
Keywords: CSCW, e-engineering, collaborative engineering, workflow, product development process

1. Introduction

Globalization today has evolved from a germinal idea into a reality that underpins many of our daily decisions. In this context, the world wide web (WWW) is a powerful tool for facilitating communications on various levels, including oral, written and graphical means. Taking advantage of these new avenues of communication, many engineering companies have developed worldwide partnerships, reducing time-to-market and costs and gaining access to new opportunities that extend their geographical range.

Current web platforms, however, lack the necessary resources to carry out all the tasks required for the establishment of engineering partnerships. Based on this premise, the e-HUB was proposed, a collaborative platform for monitoring, assisting and, when necessary, arbitrating the establishment, planning and execution of engineering contracts.

This paper describes the development of the conceptual design of the e-HUB, which is based on continuous learning and adaptation of its users' needs. This solution is called Evolutionary Concept, due to its similarity to Darwin's theory of evolution, particularly insofar as it concerns adaptation to the environment.

2. State-of-art

Collaboration among globally distributed engineering teams through the WWW is still a challenging research subject. The first generation of collaborative tools was simply a collection of tools for communicating through the Internet, as indicated by an analysis of the three-level classification model for Computer Supported Collaborative Work (CSCW) presented by DE SANCTIS & GALLUPE (1987):

- **level 1:** Electronic messaging, computer terminals, anonymous inputs, voting features and agenda features;
- **level 2:** Planning features (PERT, CPM, etc.); risk analysis, budget allocation, decision-aiding features; and
- **level 3:** Formalized procedures and rules; procedures for negotiation and expertise consulting.

The literature today offers few examples that fit level 2, and even fewer for level 3. MONPLAISIR (1999) shares this point of view, stating that the enhancements described by DE SANCTIS & GALLUPE are largely absent from most GroupWare systems.

It is important to note that collaboration is a broad concept, albeit only one of the facets of cooperative work.

Four primary elements define real cooperative work teams (PEÑA-MORA et al., 2000):

- **communication** involves the exchange of information, events and activities in any Concurrent engineering (CE) effort. Effective communication is a necessary, albeit insufficient, condition for meaningful collaboration;
- **co-location** involves dealing with the infrastructure to provide seamless communication among distributed designers and engineers;
- **coordination** involves control of the workflow and communication process, providing efficient control mechanisms to coordinate group effort. Coordination involves managing the various interdependencies between activities and events in any CE effort; and
- **collaboration** describes the process of sustainable value creation that creates a shared understanding of the CE effort.

Many organizations have attempted to create a collaborative product development environment that could meet the needs of all types of industries, projects and purposes, i.e., a universal collaboration platform. Such a platform does not exist and probably never will. Why not? According to WANG et al. (2002), the Information Technology available today should be able to connect people all around the world. Geographical distances diminish and communication is enhanced with every new IT development. These technological advances can create good communication channels, which are a crucial part of the collaboration process, especially between partners of different cultures (DAVENPORT, 1999).

However, every firm is a universe unto itself, with its own culture, language, methods, rules, standards, etc., and this makes all the difference between efficient **communication** and efficient **collaboration**. There is no doubt about the advantages of IT in communication, but what about collaboration?

MONPLAISIR (1999) describes CSCW as a technology that is being used increasingly by engineering design teams to reach a consensus on a range of design issues. In the case of geographically distributed teams, CSCW systems offer a tool that could potentially enhance productivity and effectiveness. In this author's opinion, the success of CSCW systems depends on the following characteristics:

- **interaction** in synchronous and asynchronous modes among team members;
- **coordination** of the various tasks performed by members of the team;
- **distribution** to enable people to interact from remote places;
- **visualization** and accessibility of data by team members; and
- **sharing of data**, engineering drawings, applications, etc. among participants.

The aforementioned author considers that much of the existing literature on CSCW is limited to technical matters (e.g., data processing, groupware functions, multi-media tools), while little of it deals with the role of CSCW in Product Development and Design and its effect on problem-solving activities or processes. MONPLAISIR (1999) also states that engineering teams are only willing to use CSCW systems with extensive enhancements to support the wide range of group decision-making situations occurring during a project.

HAMERI & NIHTILÄ (1997) have a similar point of view, stating that "Prior research on the networked New Product Development (NPD) process remains extremely limited". Many gaps must still be filled in today's information technology market. Our focus is on support of the collaboration process itself, from the formation of a partnership to its dissolution, including dispute solving. The literature describes new technologies to deploy novel ways of working in networked teams. LIANG & HUANG (2002) propose an agent-based collaboration system for product development. Focusing on conceptual design, WANG et al. (2002) list many technologies for enabling visualization, modeling and data sharing through the Web.

HAMERI & NIHTILÄ discuss some aspects of the importance of project planning, from the analysis of information flow throughout the project's duration to file sending and retrieval by each partner. Obviously, IT alone cannot solve every problem, but it is undoubtedly an important element for its solution.

EVARISTO & VAN FENEMA (1999) provide a typology that groups traditional and collaborative projects into seven categories, based on two variables (Figure 1): number of locations and number of projects. These authors state that organizations evolve level-by-level, according to the pattern illustrated in Figure 2.

An analysis of this typology reveals that CSCW tools to support engineering collaboration among different companies require at least a level B/type 2 project or a level C/type 3 or 4 collaboration. Based on this observation, one can conclude that enterprises aiming to work collaboratively with other companies need a prior background in conventional project management before engaging in this type of endeavor.

In addition to prior knowledge in project management, other skills are needed to successfully develop a collaborative project. HAMERI & PUITTINEN (2003) state that, excluding political obstacles, the fundamental problems that hinder the realization of project goals originate from:

1. ignorance of what other project teams are doing;
2. lack of discipline in design change control;
3. diverse views about the objectives of the project;

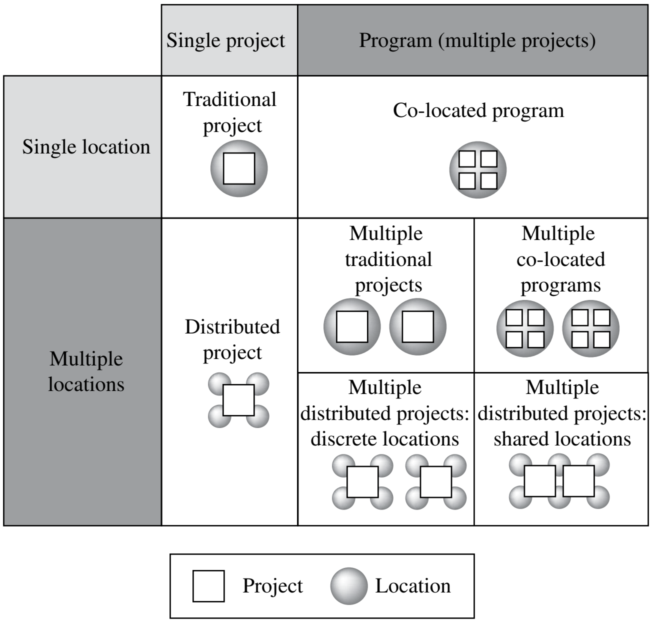

Figure 1. Project Management Typology (EVARISTO & VAN FENEMA, 1999).

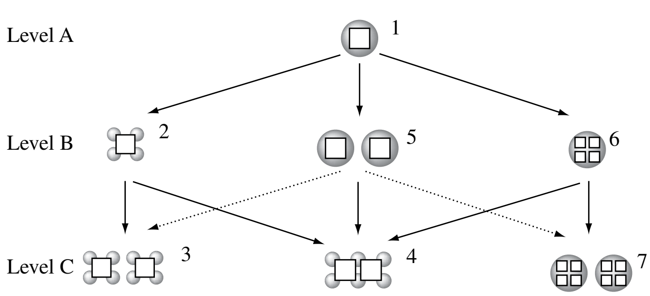

Figure 2. Evolution of Project Forms (EVARISTO & VAN FENEMA, 1999).

4. rigid project planning and scheduling routines;
5. poor reactivity; and
6. unforeseen technological difficulties

According to BRUCE et al. (1995), collaboration can provide a means of sharing NPD costs and risks. It has also been affirmed that collaboration can reduce project development time when compared with independent development.

Many large enterprises have also placed their relationship with other companies at the core of their R&D and NPD strategy, aiming to increase their competitiveness in relation to SMEs. Therefore, SMEs today have more opportunities for collaborating with large companies than for directly competing with them (NARULA, 2002).

According to KOVÁCS & PAGANELLI (2002), traditional business is obsolete. These authors believe web-based solutions offer a way to overcome the difficulties ensuing from the physically and logistically distributed nature of cooperating teams. Various efforts have been made in the last decade to develop a higher-level CSCW tool that can provide formalized procedures and rules, negotiation processes and expertise consulting. Several examples of these efforts are available in the literature. BRAZIER et al. (2001) proposes a model for establishing a collaborative distributed design with an individual designer and points out the need for reasoning the negotiation strategies of this sort of relationship, including standards and values in a culture, and deliberate norm transgression. TAMINÉ & DILLMANN (2003) present a tool that, integrated with web-process tools for managing process modeling, process simulation and optimization, process representation and process control, supports the execution of distributed construction processes in industrial environments. WANG et al. (2003) evaluate the impact of Internet-based collaborative design and manufacturing in Singapore's die and mold industry. The authors indicate that the firms they surveyed are concerned about costs, confidentiality, reliability and security in dealing with B2B e-commerce. KOVÁCS & PAGANELLI (2003) describe a Web-based project environment integrated to a workflow management system (aiming at integration among members), which provides planning and management for complex distributed organizations working on large-scale engineering projects. AVERSANO et al. (2002) describe a project aimed at introducing new technology and services within a peripheral public administration, and at transferring Business Process Reengineering Methodologies and workflow technologies to local SMEs.

As can be seen, a large part of these papers focus on a specific industrial sector or address a particular need. Some of these works, particularly the latest ones, employ workflow technologies to facilitate the collaboration process, which can be considered a tendency in the management of collaborative works, since they involve formal procedures and rules for negotiation. DE SANCTIS & GALLUPE (1987) consider these characteristics to represent the highest level achieved by CSCW tools.

According to MENTZAS et al. (2001), workflow can be defined as a collection of tasks organized to accomplish a business process. These authors state that workflow technology allows an organization to automate its business processes to better manage those processes, and hence, their outcomes. Workflows will deliver work items to appropriate users and help those users by invoking appropriate applications and utilities, allowing management and employees to track the progress of work items through the process and generate statistics on how well the different steps are progressing.

MENTZAS et al. (2001) also list three specification languages and related techniques to aid the implementation of workflow technology for business processes:

- **communication-based techniques**, which assume that the objective of business process reengineering is to improve customer satisfaction. They reduce every action in a workflow to four phases based on communications between a customer and a performer: preparation, negotiation, performance and acceptance;

- **activity-based techniques**, which focus on modeling work rather than modeling commitments among humans. Such methodologies model the tasks involved in a process and their dependencies. It should be noted that the activity-based approach is consistent with object-orientation; and
- **hybrid techniques**, which can be considered a combination of communication-based and activity-based techniques.

The project described in this paper is destined for the development and implementation of a web-platform concept that is able to support Engineering Collaboration in different industrial sectors and cultures and for different needs. However, this project does not aim at universality, but attempts to meet its users' needs based on an evolutionary perspective. This novel platform, a CSCW tool, uses available workflow tools, standards and techniques to propose a collaborative environment that can be customized to perform unique project processes for developing unique products.

3. Evolutionary concept of the platform

In his well-known The Origin of Species, Charles Darwin proposed that evolution results from the Natural Selection or Survival of the Fittest. In terms of software tools, only the ones whose features best meet the needs of their users survive. Thus, competitors in the same niche evolve and adapt to everyday changes or die. In this context, evolution is the way a software platform or company adapts to new marketing trends and needs.

The Evolutionary Concept, which is based on this premise, proposes a solution for multi-purpose collaboration systems through an "organic growth" process, whereby it absorbs new aspects of different collaborations, providing knowledge for new projects and, in so doing, evolves continuously. According to DAVENPORT (1999), tacit knowledge is an important component of innovation. In fact, some firms, particularly those involved with emerging technologies, deliberately plan to acquire tacit knowledge.

Based on the Evolutionary Concept, a collaboration platform was conceived as a group of companies from many different industrial sectors. These companies can provide services to each other and to third party companies. Each collaborative effort using this platform is expected to result in the creation of a new template of collaboration, providing best practices, standard deliverables and activities. The information contained in these templates, which comprises a substantial part of the tacit knowledge and experience of the platform's users, is deposited in a knowledge repository that can be tapped into. Figure 3 illustrates the main elements of the Evolutionary Concept.

Every company that joins the collaboration platform, be it an engineering service provider or a client, should therefore add new practices to the system, allowing for the addition of a new industrial sector from time to time. Of course, new sectors constantly appear and existing companies continually change, so it is impossible for any collaborative structure to reach a truly universal state. Thus, the platform is expected to display almost "organic", never ending growth, extending its life cycle.

The platform's evolutive process is a gradual one and, as indicated in Figure 4, it will take a considerable amount of time to reach a more "universal" level. However, when it reaches that point, it is expected to encompass almost every industrial sector and the greater part of existing negotiations, planning, execution and closing processes in engineering. This approach offers a far safer alternative than attempting to create a real universal platform from scratch, because there are innumerable industrial sectors and different companies with different needs, cultures, standards, etc. Any collaborative enterprise is unique insofar as its complexity and life cycle are concerned. It is almost impossible to create a single environment possessing all the necessary features without falling into at least one of the following traps: unacceptable generality and/or a disconnect between the environment's parts.

The evolutionary concept was, therefore, built upon the "incremental commitment" approach of Product/Project development, which balances research and implementation resources with project uncertainty, keeping risk at a tolerable level (COOPER, 1983).

It should be noted that knowledge sharing is stimulated through the very structure existing among and created by the collaborating partners. This stimulus is provided mainly by the possibility of document and template reusability.

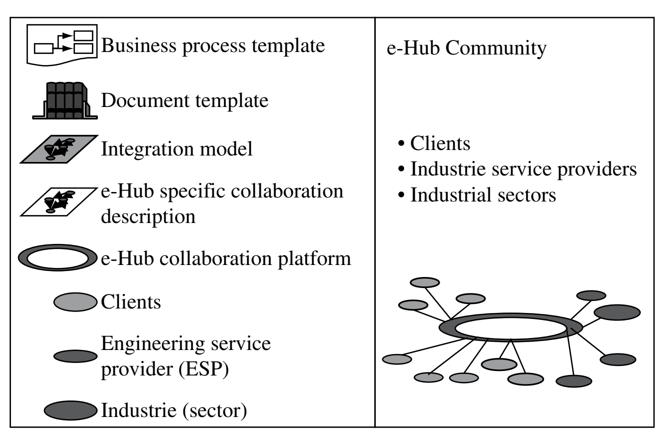

Figure 3. Main elements of the evolutionary concept.

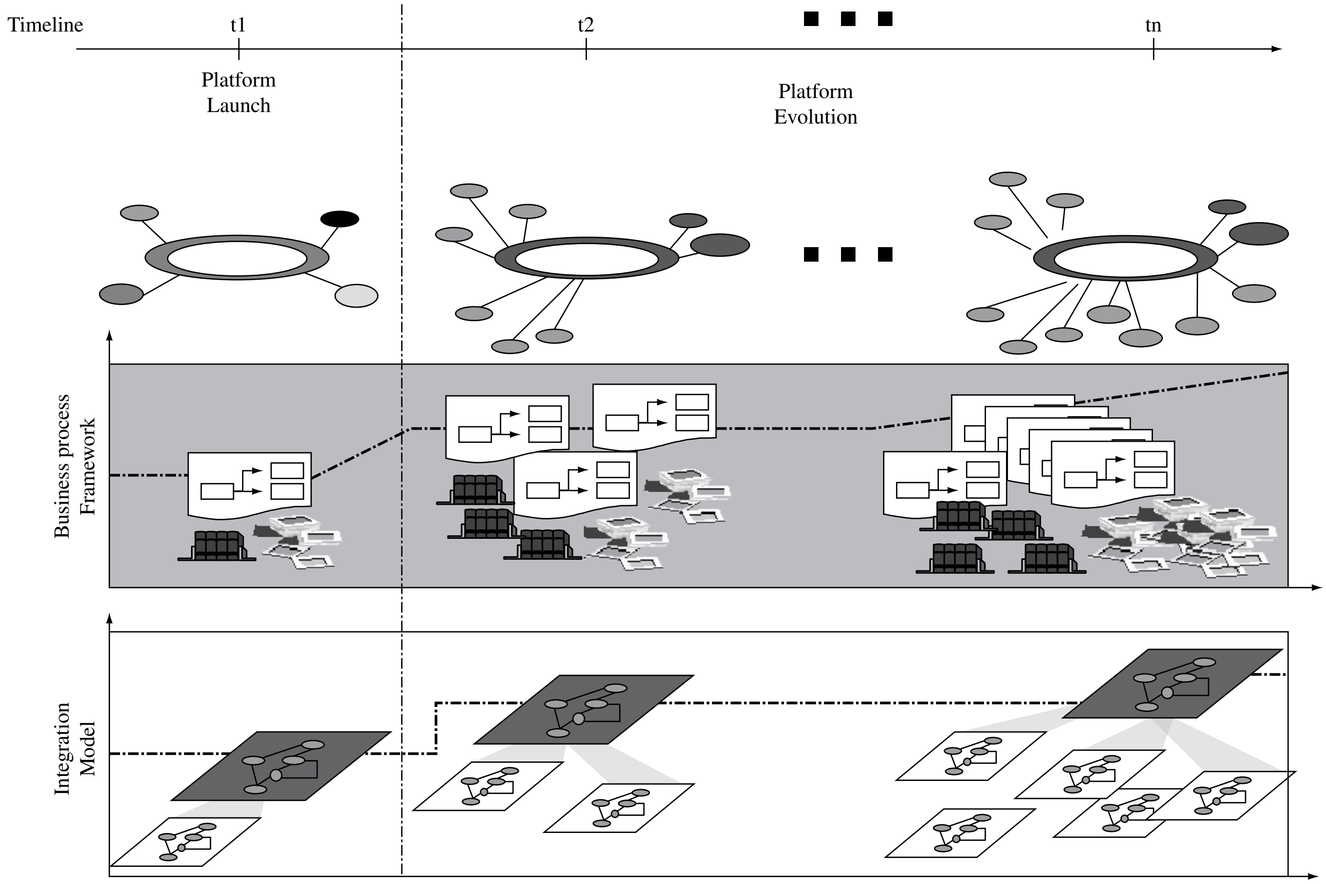

Figure 4. Growth according to the evolutionary concept.

When a user authorizes the use of proprietary information as a reference, this information becomes part of a specific knowledge domain or engineering area, and can be accessed by any other user. On the other hand, the system must keep in mind the confidential nature of some data and provide the features needed to ensure the security of the users' project information.

Evolution, as proposed here, will be achieved through the use of a customizable platform that can carry out processes involving different industrial sectors, engineering areas, cultures, collaboration needs, etc., for which workflow resources and techniques have been adopted. Thus, any enterprise wishing to engage in a collaborative project can develop its own collaboration process or, if available, use existing workflows, adapting them to its specific requirements.

It is important to grasp the difference between workflow evolution and platform evolution. The former occurs through the modification of the workflow description. The latter, on the other hand, should come about through the addition not only of new functionalities and technologies but also, according to the Evolutionary concept, new workflows, documents and templates to the platform.

The following pages describe how the Evolutionary Concept was developed to support customization through workflows.

4. Concept development

Even a growing organic structure must have a foundation. Therefore, the ideal point at which to start must be defined. The factors to be considered may involve many different dimensions, including industry, the stage in the life cycle of the collaboration, the partners' maturity in project management, the project's interface complexity, the partners' technical knowledge within the project domain, the level of trust among partners, the mutual trust between the partners and the platform broker, the available IT, the company cultures, legal concerns, etc. This list could go on indefinitely, and it would serve no purpose to attempt to cover every possible variable within every dimension.

Therefore, a short list of dimensions was chosen for this project and, following the evolutionary principle, the overall conceptual structure was created so as to easily accommodate additional dimensions or variables within these dimensions as needed. These chosen dimensions are:

- stages of the collaboration life cycle;

- industrial sector; and
- collaboration complexity (number of partners, project interface complexity, etc...).

4.1. Collaboration life cycle

This dimension is considered one of the most basic and important elements. The Collaboration Life Cycle was divided into five stages:

- **stage 1 - project definition:** the Engineering Service Provider (ESP) or Client decides what to partner. The type of service offered by the collaboration platform is a hybrid mix of business consultants and automated performance measurements of uploaded business processes;
- **stage 2 - finding the right partner:** type of service: automated prospecting, online portfolios and expertise profiles. In addition, human services are offered for legal and trade services on demand, precertification, validation;
- **stage 3 - planning the collaboration:** This is based on the following set of services: automated process negotiation augmented by human services when needed, such as legal support (hiring), dispute resolution, arbitration, banking/credit options;
- **stage 4 - executing the project:** the output of level 3 is imported through a mapping interface that maps the project plan of stage 3 onto the set-up of the collaboration workspace; and
- **stage 5 - dissolving partnership:** includes capture and storage of audit trails from collaboration workspace, aggregation of audit trails in partner rating, application of knowledge retention metrics.

These stages were divided into three maturity levels, each representing a different implementation level of the collaboration platform. Figure 5 illustrates the various maturity levels of the platform and the "project states" that define the beginning and end of each stage. The initial efforts concentrated on the development of the Maturity Level-1 prototype, which is considered the core, i.e., the most crucial, process of the collaboration process.

Due to the importance of a well-prepared project plan to correctly define the collaboration process, stage 3 of the collaboration process was chosen as the initial focus of development. Stage 3 was also chosen due to its potential for innovation at this point of the process, and because it is considered the most challenging research subject, which became evident in our evaluations of the technology and techniques available for the previous stages of collaboration through the WWW, i.e., web-forms for stage 1 and database searches for stage 2. Stages 4 and 5 involve other interesting subjects, but they depend on the successful implementation of stage 3.

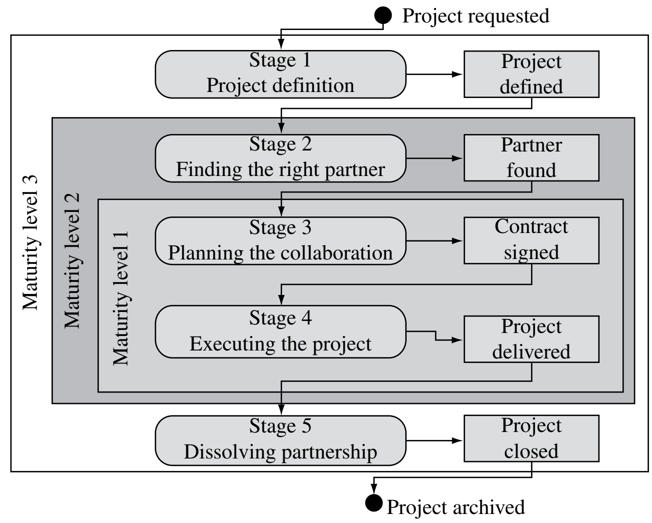

Figure 5. The Five Stages of Collaboration.

4.2. Industrial sector

Two industrial sectors were considered and evaluated during the development of the Evolutionary Collaboration Platform: the AEC and Mechanical Engineering Sectors. This choice affected the design process of the platform from its very inception. Prior to the development of the platform, three engineering cases were evaluated. These cases describe collaborations between Small and Medium Enterprises (SMEs) in different industrial sectors. They were prepared based on the past experience of partners in a consortium and on an extensive bibliographical review of reported project scenarios. Theses cases were explored in detail, as follows:

- **case A:** a scenario in which two companies involved in a construction project identify the need for a seismic risk analysis. They contact the collaboration platform and find a supplier of this specialized service. This case allowed for the identification of a partnership, as well as some secondary roles that may emerge during a multi-party collaboration (legal, technical, etc.);
- **case B:** a different version of the previous case, in which various aspects of concept planning and development of the final product are discussed in greater detail. This case requires a more elaborate planning phase, especially in terms of the culture of partnering and contracting in the construction industry; and
- **case C:** more than just a single case, it presents a set of four types of product development business models identified and described in a Mexican cluster of SMEs. The specific case concerns the development of mechanical products for the aerospace industry.

These cases served as the basis for modeling the collaboration process using the platform. The model, called Preparation Model (AMARAL et. al, 2004), was developed using UML (Unified Modeling Language) and shows the process involved in establishing a collaborative effort, starting from the identification of a partner to project planning and concluding upon definition of the project's deliverables and phase reviews.

The industrial sectors are important dimensions for other deliverables of this project, such as designation of e-Engineering services, platform tests and development of the platform itself, including organization of the project's templates and documents.

4.3. Interface complexity

Among the chosen dimensions, interface complexity is the one that deals with the greatest number of variables. The number of partners, legal differences, project interactions and expected deliverables are but a few examples that illustrate the difficulties of dealing with this dimension. However, it should be noted that a complex product does not necessarily mean a complex project. The former involves complex technology and the latter complex relationships.

To develop an initial portfolio of workflows, interface complexity was employed in different ways according the requirements of each workflow category. Examples of this directive are given in the "Workflow Collection" presented next.

5. The "Workflow Collection"

In this project, the initial portfolio of workflows has been dubbed the "Workflow (WF) Collection". This portfolio, whose development was based on the dimensions and constraints described earlier herein, aims to provide a starting point for the establishment of partnerships through the collaboration platform. The workflows were designed based on the activities of the aforementioned collaboration model. This model, which represents a general and domain-free process for establishing an e-Engineering partnership, was used as an outline and was divided into specific collaboration processes (the workflows).

To support the Evolutionary Concept, the collaboration platform was conceived as a two-level system: the Basic Collaboration Platform (BCP) and the Integrated Project Platform (IPP). The BCP combines all the functionalities needed to establish the basis of collaborations, including e-mail, chat-rooms, meeting agenda, calendar, document repository, etc. The BCP also provides an initial page that summarizes current project information, including active workflow processes, messages sent and recently posted documents.

The IPP, which can be accessed through the BCP, contains the functionalities for negotiating, storing, planning and controlling project data, including task lists, scheduled project meetings and lists of documents. It should be noted that all the core project activities, such as project planning, acceptance of deliverables, phase reviews, conflict mediation and expert consulting, were designed as a customizable portfolio of workflows.

A detailed diagram of the structure of the integrated BCP and IPP platform is shown in Figure 6. Figure 7 shows how the phases of the collaboration process (the Project Preparation Model) are related to the proposed functionalities of the platform. The BCP is the lowest layer of the software platform, since it comprises the most common collaboration tools. A specific layer is reserved for the specific engineering services to be provided by the collaboration platform. The second and fourth layers contain the WF Collection, which is composed of dedicated collaboration workflows and supporting workflows. These three elements make up the IPP and are described in detail on the next topics of this paper.

All the elements arranged on the software platform are closely related to a specific stage of the business process of the company responsible for providing the brokerage service and maintaining the collaboration platform. The business process is closely related to the stages of the life cycle of the collaboration and should correspond to one of its deployments. It is important to emphasize that, for initial implementation purposes, only the features of stage 3 of the collaboration were developed. The other stages will be provided during the platform's evolvement, following the principles of the Evolutionary concept.

5.1. Collaboration workflows

To establish the initial workflow portfolio, the Project Planning phase was divided into three different types of workflows: Project Charter, Scope Statement and Project Plan (as indicated in Figure 7). Each workflow is able to deal with different applications, forms, documents and data embedded in the BCP, which act as a front-end application of the platform. Once a new project starts, the system, a user or a system administrator of the system defines which workflows and their variants will be enacted. The Project Planning workflows are described below:

- project charter: the formal authorization of a project;
- scope statement: the basis for making future project decisions and for confirming or developing a common understanding of the project's scope among the stakeholders; and
- project plan: the formal documentation of the contents needed to manage the project's execution. This plan includes activities, tasks, technical decisions, etc.

The initial WF Collection provides five workflows for the Project Planning phase (Figure 8). These workflows represent different levels of project complexity, dealing

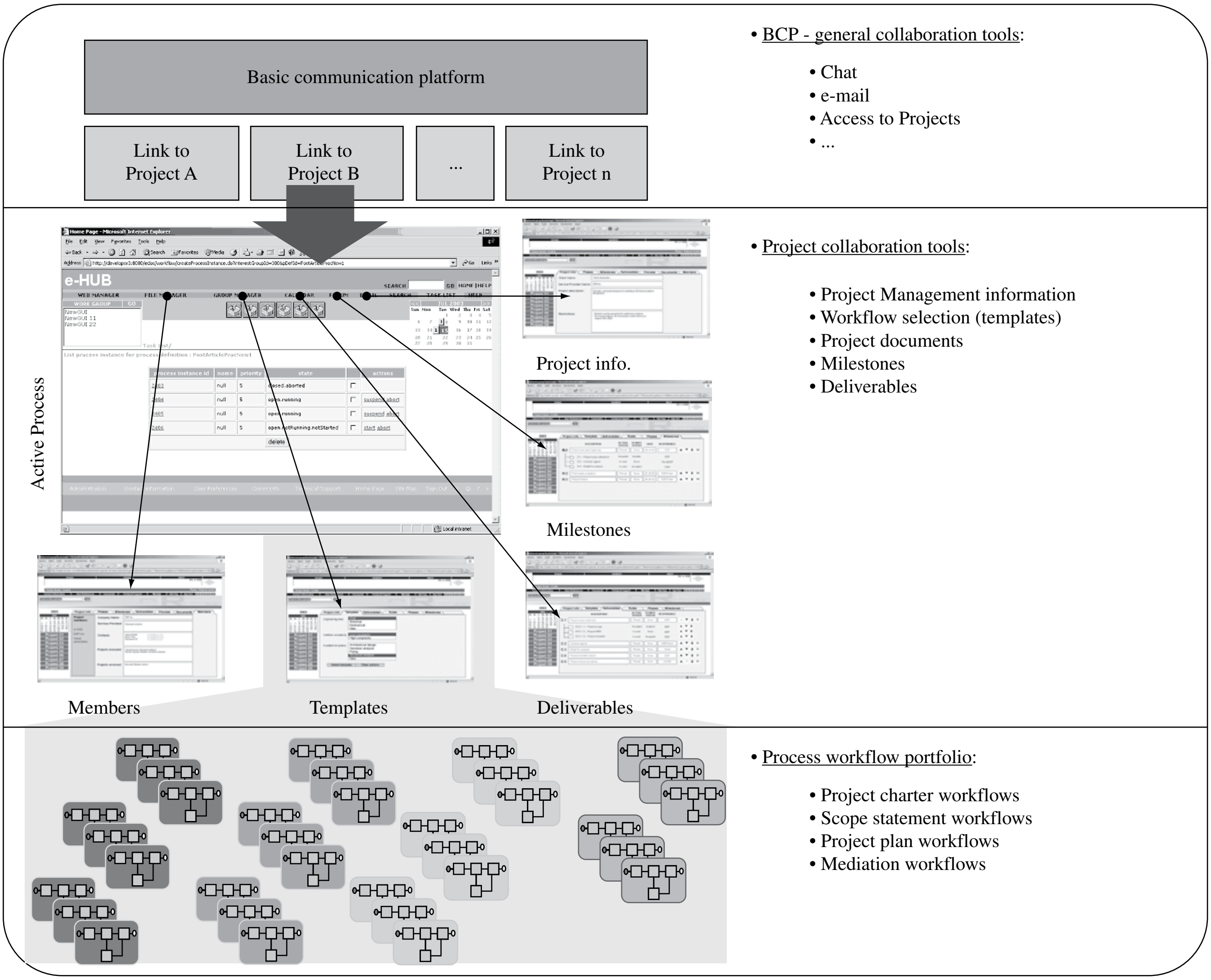

Figure 6. Structure of the proposed collaboration platform.

with two different variables: the number of partners and the maturity of the relationship. This initial portfolio allows a project to be planned in three distinct ways. Note that these workflows were designed to be domain-free and easily customizable by the platform's future users. The initial portfolio of collaboration workflows is:

- **PC_1E_HC:** Project Charter for High Complexity partnerships with one contractor and one Engineering Service Provider (ESP);
- **PC_2E_HC:** Project Charter for High Complexity partnerships and Two ESPs;
- **SS_1E_HC:** Scope Statement for High Complexity;
- **SS_2E_HC:** Scope Statement for High Complexity and Two ESPs;
- **PCSS_1E_LC:** Integrated Project Charter and Scope Statement with one contractor and one ESP. Designed for high maturity relationships where there is no need to enhance trust among partners; and
- **PP_1E:** Project Planning workflow. This workflow defines the deliverables of the project and the phase reviews needed.

Despite the directive of focusing on stage 3 collaboration, workflows for Deliverable Acceptance and Phase Reviews were developed for purposes of evaluation. These workflows are directly related with the final results of PP workflow and their development was considered mandatory by the project team.

It should be emphasized that the flexibility of the collaboration depends entirely on the number of workflows created. Following the evolutionary concept, more workflows can be included in the near future to support different types of collaboration, broadening the scope of the WF Collection. Figure 9 illustrates the evolution of the

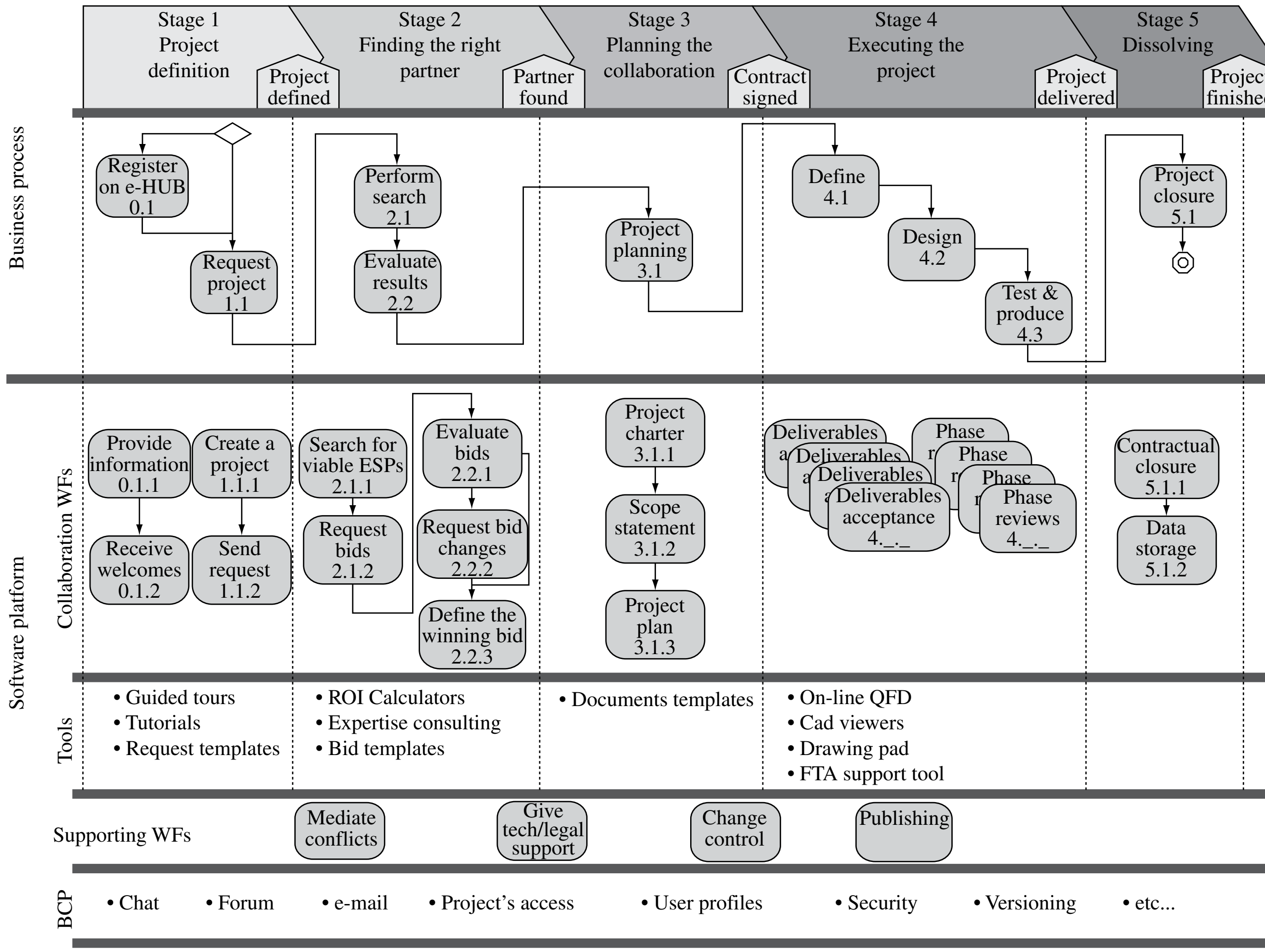

Figure 7. Overview of the integration between BCP and IPP.

collaboration workflows for collaboration stage 3 in terms of two variables: Interface Complexity and Relationship Maturity. As discussed earlier, the evolution of the WF Collection should include other parameters, such as the industrial sector, number of partners, etc.

The aim of the collaboration workflows that comprise the initial portfolio of the Workflow Collection is the definition of project deliverables and milestones for project monitoring, which are called phase reviews. According to HAMERI & PUITTINEN (2003), "providing information about project status leads to self-organization and inside-out project reorganization and co-ordination that bypasses all levels of management". These authors state that self-organization is a new paradigm that has been observed in virtually every community that evolves on the Internet, which is characterized by leaner management structures and by the shift from process-oriented projects to task-oriented projects. Thus, tasks can be submitted to their performers, who carry them out on their own basis.

The collaboration workflows, which were created by a similar rationale, should be used to coordinate the distribution of tasks among project partners, who presumably have the capacity to deploy and coordinate them. This presumption of prior knowledge in project coordination is not a fallacy, but an observation that any enterprise has at least a minimal competency to execute what it offers. This view is supported by the works of EVARISTO & VAN FENEMA (1999), as presented previously in the introduction of this paper. In the absence of such competence, the platform should provide mechanisms for correcting deviations from the scope of the project. Some of these mechanisms are described below.

5.2. Supporting workflows

In addition to collaboration workflows, the WF Collection also provides supporting workflows. However, these types of workflows should be considered as an independent portfolio of workflows, since they are not directly related to the main flow of the business process. The supporting workflow collection comprises:

- **technical/legal support request workflow:** designed to allow a project's partners to request legal or technical support from the project's broker. If

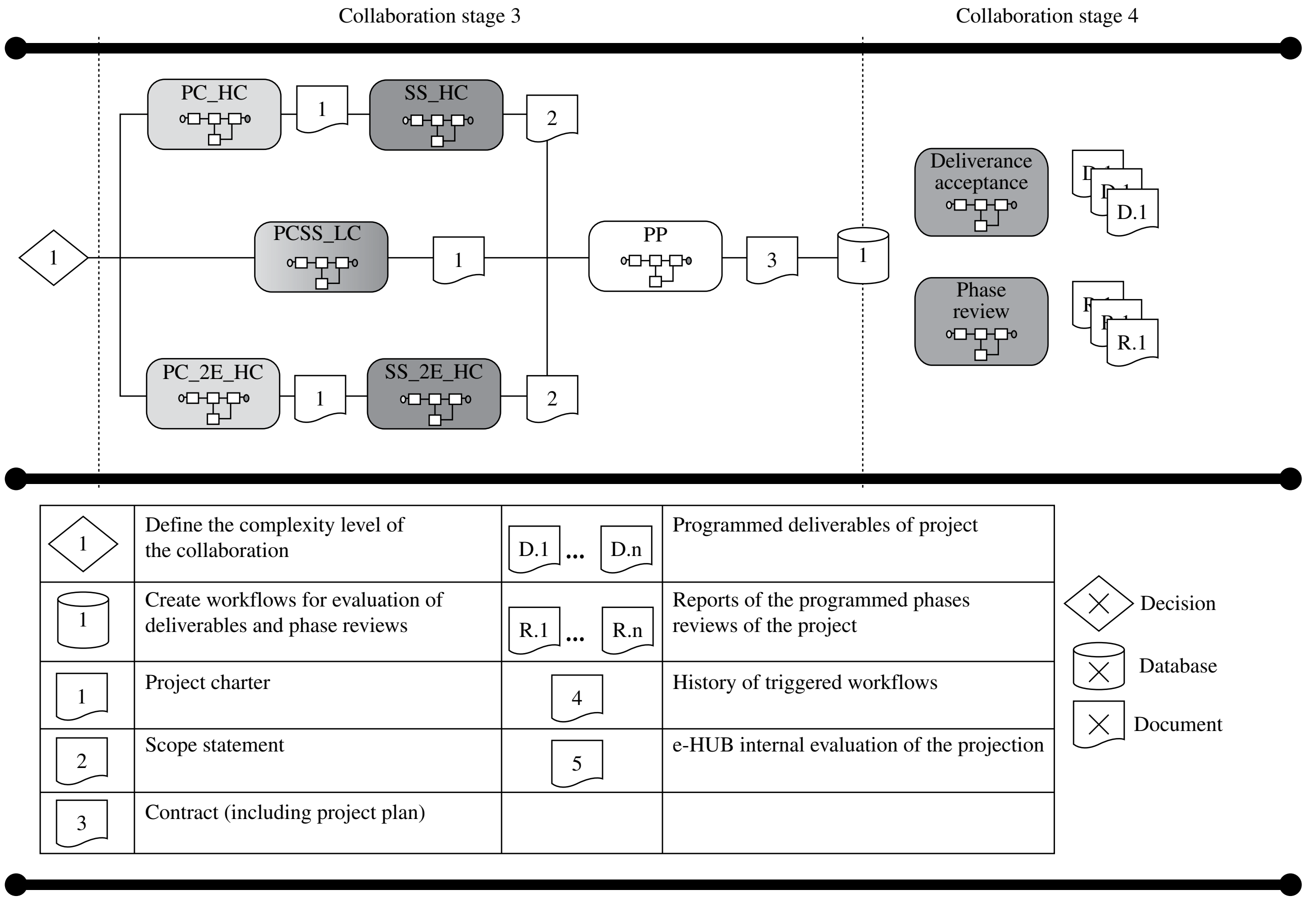

Figure 8. WF Collection – initial portfolio of collaboration workflows.

necessary, the broker should suggest hiring a third-party expert;

- **change control workflow:** this workflow should be enacted every time changes in previously defined deliverables are required;
- **publishing request workflow:** if one or more partners want to publish some of the results of their project or any other information, they can use this workflow to make their request directly to the platform administrator; and
- **mediation workflows:** during the development of a project it is common for misunderstandings or conflicts to occur. In such cases, the project broker can instantiate a mediation workflow.

The mediation workflows were developed based on criteria of "mediation complexity", which is directly related the level of involvement of different viewpoints and domain experts. This determines the degree of interactions and potential points of concern or disagreement that may occur between the experts during the project execution. As illustrated in Figure 10, mediation complexity covers three workflows, ranging from the simple consulting of an expert to a judgmental process with five experts. In the middle of this process we found a consultation with three experts.

Other workflows, such as risk analysis, should be added to the supporting workflows of the WF Collection in future.

6. Workflow embodiment

The workflows were embodied using a modified version of the Enhydra JAWE tool provided by another member of this project consortium. The functionalities of this tool are the same as those of the original, but it was enhanced to better meet the requirements of the IPP interface, which works as the system's workflow engine.

All the processes were designed based on a negotiation procedure (AMARAL, 2004) defined on the collaboration model described earlier (Preparation Model). The negotiation procedure, whose appearance is the same in all the processes, as indicated in Figure 11, is composed of the following activities:

- **propose:** Each negotiation process must begin with an initial description or document. For the initial workflow collection, the initial proposals for the Project Charter are provided by the customer (con-

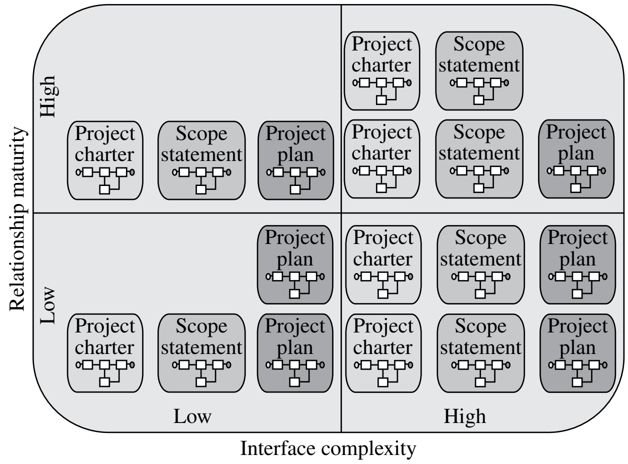

Figure 9. Evolution of collaboration workflows of stage 3 collaboration.

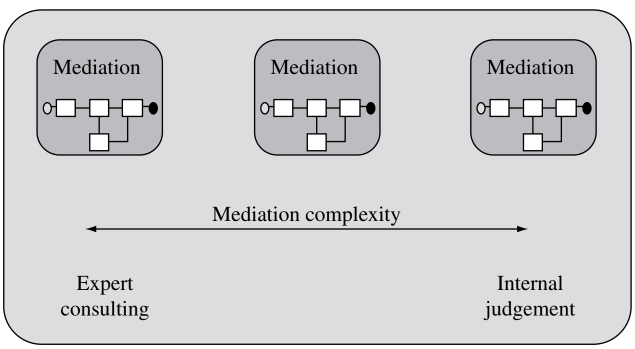

Figure 10. Mediation complexity.

tractor) and, for the Scope Statement and Project Plan, they are presented by the Engineering Service Provider(s) (contracted);

- **check:** After a proposal (or a Modify activity), all the information must be evaluated by the project partner(s), who decides to accept or modify it. If the proposal is refused, the change requester is prompted to provide the changes needed (modify activity). Otherwise, the platform's enactment system calls the Select activity;
- **modify:** If a partner wishes to change any information provided previously (Check activity), he can do so during this step of the negotiation process. All the changes made during this step should be evaluated by the other partner(s) in another checking activity; and
- **select:** Once the negotiation looping ends, the systems prompts the platform broker to select the next workflow to be enacted (a scope statement or a project plan).

All these activities are connected by route activities, which define the next step of the negotiation process based on the information provided by the participants of the process. It is also important to note the use of the "select" activity at the end of each negotiation procedure. This approach allows the newly developed workflows to be used and reused in the future, and new processes to be added over time.

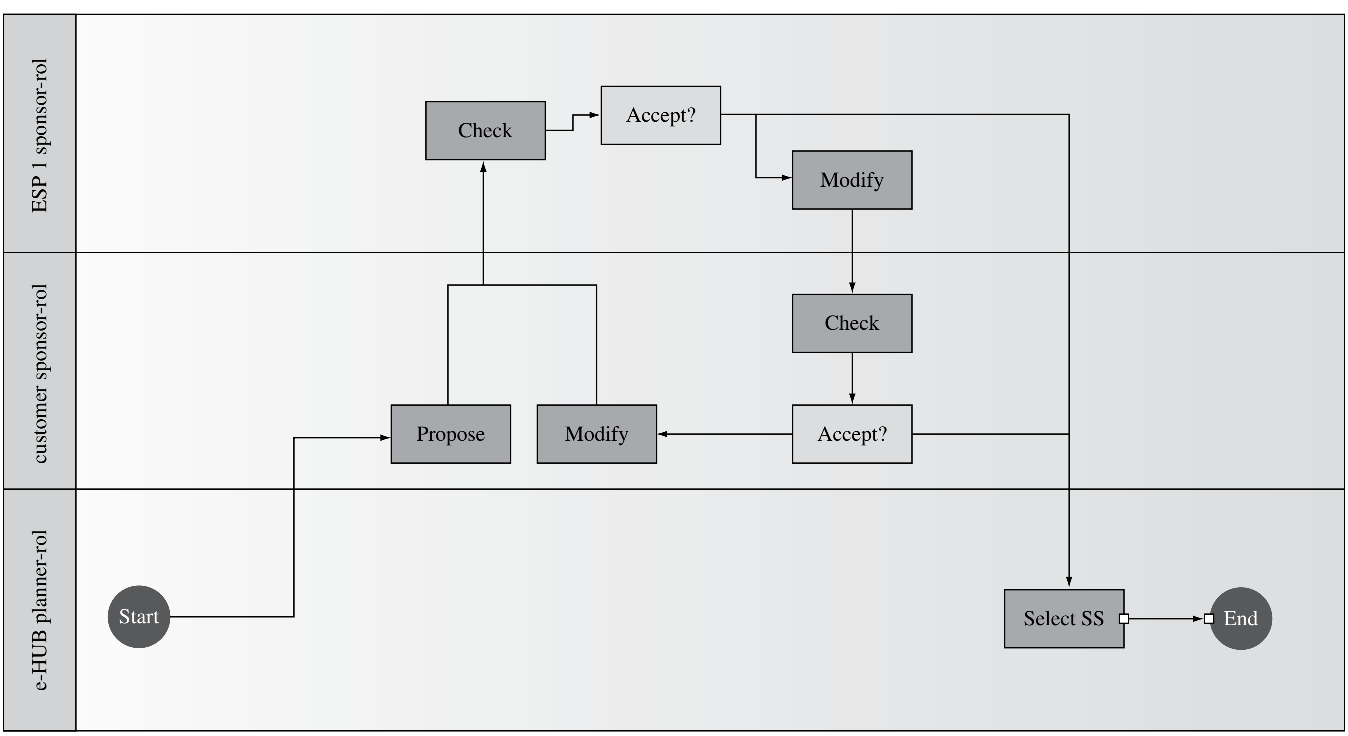

Figure 11. Example of a workflow negotiation procedure for Project Charter.

The differences among developed processes lie in the contents of the activities, which define the content, access, type and appearance of the fields of the web form to be displayed to the participants in each step of the negotiation process. Table 1 shows the content of the developed collaboration workflows.

A contract is generated at the final round of negotiation of the Project Planning workflow. An initial version should be created by the collaboration platform, based on a contract template (including standard clauses for environmental issues, general conditions, confidentiality, responsibilities, penalties, intellectual property and constraints) and the information provided from the Project Charter to the Project Plan. This initial version is negotiated until an agreement is reached. All supportive workflows should be used during this negotiation. It is worth emphasizing that the initial Workflow Collection is only a basis, and can be enacted as it was created or customized to meet the needs of a particular collaboration.

It is also important to note that other members of the project consortium were responsible for the embodiment of the enactment platform (IPP) and the front-end interface (BCP).

7. Final comments

The Evolutionary Concept proposed here is an approach for a new generation of CSCW tools for e-Engineering collaborations through the Internet. The Evolutionary Concept makes use of workflow technology to ensure the extended life of the proposed collaboration platform. The use of workflows allows for better adaptation to the Internet environment, which is considered highly dynamic and requires a very flexible resource to deal with an immense range of user needs. As conceived, the collaboration platform should adapt to the environment through workflow customization rather than through modifications of the platform itself, thereby postponing its maturation and decline.

Table 1. Core parameters of the collaboration workflows of the Workflow Collection.

Workflow file name	Core parameters
PC_1E_HC PC_2E_HC	Project title Project objective Business need Product description Total cost estimate
SS_1E_HC SS_2E_HC	Main technical characteristics Major deliverables Constraints Milestone/Gate description
PCSS_1E_LC	Project title Project objective Business need Product description Main technical characteristics Major deliverables Constraints Total cost estimate Milestone/Gate instructions
PP	Deliverable title Deliverable description Phase review title Phase review description

The Evolutionary Concept naturally leads to the notion of "universality", which, based on the project's purposes, can be understood as a multi-engineering collaboration platform. Of course, this kind of universality depends on several factors, including demand, platform administration, technical investment, etc. However, in its present stage of development, the platform conceived to support the Evolutionary Concept is still very limited. On the other hand, this platform has already been prepared to support project preparation in the AEC and mechanical engineering sectors. It is also worth noting that the platform's evolution should involve the use of other dimensions besides the addition of industrial sectors, including the ones described in this paper.

Important technical achievements should also be listed. Taking into account the classification model presented by DE SANCTIS & GALLUPE (1987), the platform concept presented here allows for level-3 collaboration, since it provides formalized rules and procedures for negotiation and for access to expertise consulting. The two-level system (BCP and IPP) of this newly conceived platform also allows for all the elements described by MONPLAISIR (1999) to ensure success: interaction, coordination, distribution, visualization and sharing of data. Evaluating the proposed system through the typology of EVARISTO & VAN FENEMA (1999), one finds that type 3 and 4 collaborations, which involve different locations in the same project, are the platform's core elements. If all the proposed functionalities of the platform are utilized correctly, five of the six problems described by HAMERI & PUITTINEN (2003) are reduced or at least minimized.

Another important issue is the proposed platform's conformity to the new self-organization paradigm. The basis of this principle lies in the trust that each partner will do what he has committed himself to. It presumes that each partner has developed management skills to perform his own tasks. As stated earlier, this is not a fallacious assumption but was mentioned in the work of EVARISTO & VAN FENEMA (1999).

In addition to the technical achievements described here, this paper makes significant contributions to the access of SMEs to the "world of global collaboration". Compared with available retail CSCW systems, this novel platform allows for lower access and investment costs. The platform should provide access to a large number of enterprises, increasing the opportunities for new projects.

Tests performed on this platform by other members of the project consortium confirmed the flexibility of the platform and the rightness of the proposed concept. Two processes were enacted involving two different companies, one of which provides civil engineering services, while the other carries out risk analysis in mechanical engineering.

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