Collaborative Engineering Environments for Virtual Organisations

Article *in* International Journal of Information Technology and Management · April 2009

DOI: 10.1504/IJITM.2009.024607 · Source: DBLP

International Journal Information Technology and Management, (2009), Vol. 8, No. 3, pp. 298-320,
DOI: 10.1504/ IJITM.2009.024607, Inderscience Publisher, ISSN: 1461-4111 (Print) 1741-5179 (Online)

COLLABORATIVE ENGINEERING ENVIRONMENTS FOR VIRTUAL ORGANISATIONS

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Abstract. Collaborative Engineering Environments (CEE) have become important in Virtual Organisations (VO), they enable collaboration among engineering groups, supported by tools and methodologies that allow knowledge sharing and engineering activities in real time, regardless of their locations. A platform that integrates and facilitates VO operation focused in manufactured product development, is an important tool that supports a rapid respond to customers, and improves communication among its members. This paper presents a CEE methodology implemented in a real manufacturing VO, for improving the product transfer process where coordinators of each business opportunity easily manage VO partners and information during the VO operation.

Keywords: Collaborative Engineering Environments, Virtual Organisations, System Engineering, Product Transfer.

1. INTRODUCTION

Nowadays, traditional serial process of product design and manufacture is replaced by a concurrent design approach that drives in an integrated product development process. Market conditions have led to an upgraded concept where collaborative design must be achieved to support virtual product realization in the new information era.

Specially, when SME (Small and Medium Enterprises) are involved in the introduction of a new product, the use of the Virtual Organisation (VO) model represents a strategic advantage for these enterprises, making the product development process more efficient and competent, because each organisation participates in the engineering process sharing only its core competencies.

Consequently, it is important to understand the VO model, which is defined by Camarinha-Matos & Afsarmanesh (2004) as "temporary alliances of organisations that come together to share skills or core competencies and resources in order to better respond to business opportunities and produce value-added services and products, and whose cooperation is supported by computer networks". In order to accelerate the VO creation the Virtual organisation Breeding Environment (VBE) was established. A VBE is a pool of organisations (members) and their related support institutions that have both the potential and the interest to cooperate with each other, through the establishment of a long-term based cooperation agreement (Camarinha-Matos & Afsarmanesh, 2004).

One important issue during the life cycle of the VO (creation, operation, evolution and dissolution) is the collaboration environment that supports its processes, especially if the VO offers engineering services in a global environment. Engineering services include all the services and activities related with the Integrated Product, Process and Manufacturing system Development Process (IPPMD). IPPMD integrates all the activities, methods, information and technologies to conceive the complete product life cycle, where the term product includes process and facilities (Tipnis, 1999).

For VOs that offer engineering services, a Collaborative Engineering Environment (CEE) becomes really important, especially during its creation and operation. CEE supports coordination, collaboration and information management processes in a VO aimed to share competencies for engineering process.

CEE has been defined by several authors using diverse definitions and names as, Collaborative Design Environment (Shen, 2003), Web-based manufacturing system (Yang & Xue 2003), Virtual CEE (Aca et al, 2003), Virtual Workspace System (Heckel, 1997), and Collaborative Development Environment (Wang & Zhang 2002). However, the common definition is an environment that enables collaboration and interaction among partners on the development of a project regardless of their locations and incorporating information and tools according to an engineering activity. One important reason to use this kind of environments is that product and services are being developed by project work teams distributed into different areas of a company or associated to several companies onto a common project and not necessarily in the same location. This definition is then consequent with the VO model; however in this definition, the temporal alliance concept has to be included.

During the last years, several authors have presented their researches and proposals regarding the involvement of CEE and VO models. Some of them (Kesseler & Kos, 2005) address the necessity to implement CEE in VOs, for the specific design of an aircraft motor, remarking some successful required conditions and the benefits of this implementation but they do not explain or present a specific support methodology for a suitable implementation of CEE in VOs. Other Authors (Vila, Romero and Contero, 2004), have focused their efforts in developing a collaborative assessment methodology during the creation of a CEE, allowing an adequate transition, but they refer mainly to the Extended Enterprises Model; this proposal is very limited because it only tackle the measurement of changes during the analysis of product development process in Extended Enterprises, thus it does not include a complete an extensive implementation methodology. Santos, Raposo and Gattass (2006) present a service-oriented architecture (CEE) for engineering projects (VOs) based on the development of three different technologies; this investigation is just a part of what it could be an entire methodology since it keeps out further features and characteristics needed to develop and implement a Collaborative Engineering Environment in Dynamic Virtual Organizations.

The main contribution of this paper is then, to propose a generic methodology that supports the implementation and development of Collaborative Engineering Environments in Virtual Organisations.

An important issue in the development of CEE is the integration of applications and tools that enable exchange of information and knowledge among engineers in a VO in an effective and efficient manner. These integrated environments must enforce four engineering dimensions: processes, information, organisation and technology. Mejia et al (2006) proposes a methodology for design and integrate CEE in individual companies; the contribution of this methodology is extended in the VO scope on this paper. Consequently, this methodology is limited to develop CEE in VOs located in different regions that are focused in the product development process. One important consideration in that this methodology is validated in a case study wherein the VO members manage the same language (English) and semantics which reduce the complexity of this CEE implementation.

The present work has two main objectives: 1) to present a methodology for implement Collaborative Engineering Environments in Virtual Organisations (CEE-VO methodology) that are mainly focused on product development process; and 2) to describe the implementation results of this CEE-VO methodology in a real VO.

2. ACTION RESEARCH METHODOLOGY

Action Research Methodology (Dick, 2002) was used in this research to validate the CEE methodology in a VO context. Four stages were carried out: Plan, Act, Observe and Reflect.

Main activities Planed according to Plan Phase were:

1. *Methodology review and First CEE-VO Methodology Draft:* researchers analyzed the CEE methodology proposed by Mejia et al (2006) and identified issues to adapt regarding its application in a VO.
2. *Identification of performance measurements and successful factors for the adaptation of the CEE Methodology in VOs.* Avison (2001) remark that Action research has much potential for the information systems (IS) field, because represents a potentially useful qualitative research method. In this way, quantitative and qualitative indicators that can impact the CEE implementation in a VO were proposed. These performance indicators are related to the VO competitive strategy definition, which can be classified, in general terms, as: product innovation, operational excellence and/or costumer focus. According with the strategy defined, the Key Performance Indicators (KPI) can be selected as showed in Table 1.

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Table 1. Guidelines for Strategy Definition and KPIs Selection

BUSINESS STRATEGIC ELEMENTS	**KEY PERFORMANCE INDICATORS PROPOSED**
Product Innovation	• % sales of new products • ROI • Operational cost
Operational Excellence	• Quality • Volume • Time • Costs • Flexibility • Reconfigurability • Environment
Costumer Focus	• Costumer loyalty • Incidence of product defects • Safety • Time

Main activities according to Act Phase were:

1. *Application of the new CEE Methodology in a real VO:* definition of the case study and the project implementation plan (technical and human resources, project timeline) were developed.

The Main activities of the Observe and Reflect phases were:

1. *Evaluation of all the Key Performance Indicators (KPI) selected*, and identified which reasons in the implementation could impact these KPIs.
2. *Validation of results in the case study and improvements of the final adaptation of the CEE-VO methodology.*
3. *Propose and apply changes in the CEE original methodology for its application in a VO.*

After developing the Observe and Reflect phases, the Main results of AR methodology were:

- A particular model of the CEE methodology was developed (CEE-VO). The four stages of the methodology were focused on the analysis of a collaborative network instead of a single enterprise, and the VO inheritance process was introduced.
- A set of specific requirements of CEE in the context of Virtual Organisations were also identified.

The CEE-VO methodology presented in this paper already includes the modifications that were done during all stages in the AR execution.

3. CEE-VO METHODOLOGY

This methodology supports the implementation of CEE in VOs, specially focused on product development process. The methodology is based on the life cycle model for integrated product, and process development, and consists in four stages (see Figure 1). In Figure 1, is described the whole methodology using IDEF0. This modelling is developed to identify the information, controls and mechanisms that are involved in each stage of this methodology proposed. In this model, is defined a collaboration engineer, which is the manager of CEE implementation.

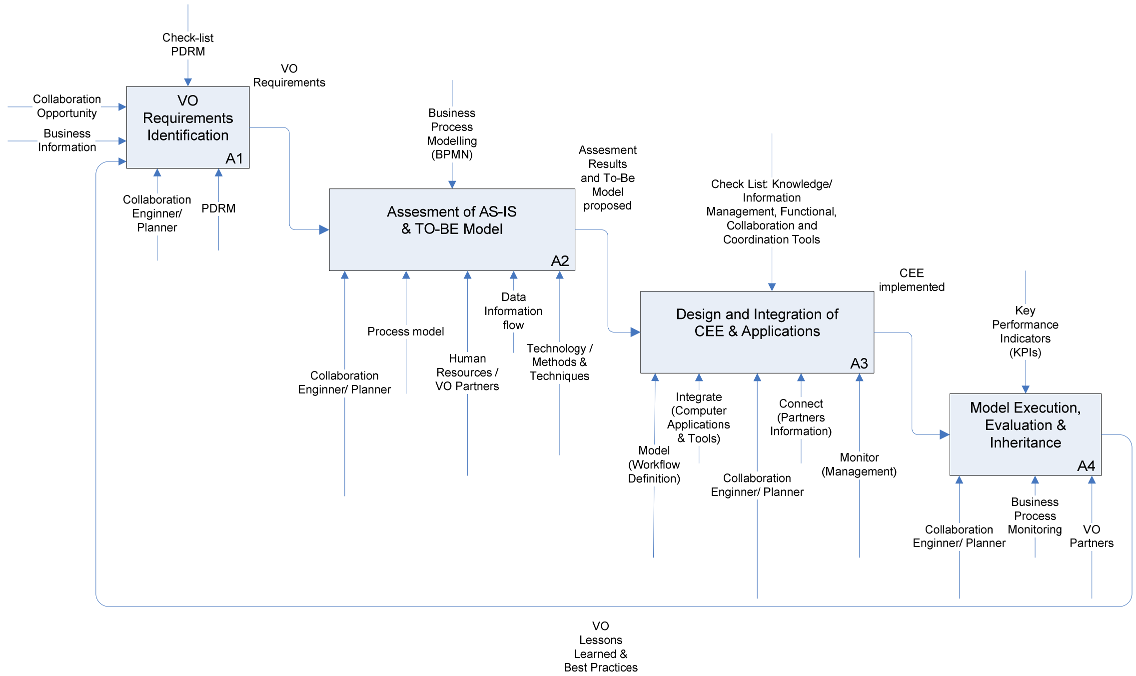

Fig. 1. Methodology for VO Process Improvement using CEE

3.1 Stage I: Identify VO Requirements in the Product Development Reference Model (PDRM)

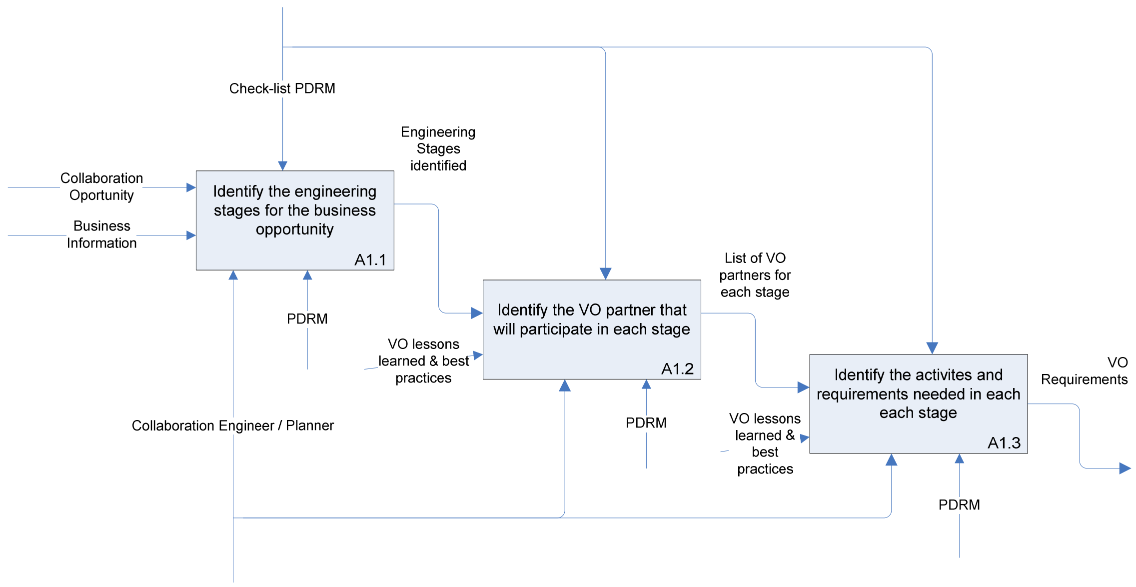

Fig. 2. Identify VO Requirements in the Product Development Reference Model (PDRM) modelled in IDEF0

In this stage, there are two information inputs, (1) Collaboration opportunity and Business information. With these two inputs are identified the VO requirements using two mechanisms: (1) Collaboration engineer/planer and (2) Product Development Reference Model (PDRM). The PDRM is supported by a map that represents the stages of product lifecycle management (Aca 2004). Figure 3 describes a map for engineering stages of the three entities life cycles: product design, process design and manufacturing system execution. According to this map, the VO should identify the type of business opportunity that will be dealt including the activities and its requirements. The stages defined in this map are: (1) Product Design, which refers to the definition of a new product from the idea to the prototype, and (2) Process Design, which refers to the definition of a manufacturing process from the specification identification to the ramp up production and (3) Manufacturing System Execution, which describes the manufacturing, control and delivery of the manufactured components.

Finally, VO requirements are defined, including who are the VO partners and which will be the activities developed.

	Conceptualization	Basic Development	Advanced Development	Launching
Product Design	PRODUCT IDEA	CONCEPTUAL & TARGET SPECIFICATION	DETAILED DESIGN	PROTOTYPE
Process Design	INDIVIDUAL COMPONENT SPECIFICATION	PROCESS SELECTION	OPERATION PLAN	RAMP UP PRODUCTION
Manufacturing System Execution	INDIVIDUAL COMPONENT SPECIFICATION	MANUFACTURING & CONTROL	MANUFACTURED COMPONENTS	COMPONENT INTEGRATION AND DELIVERY

Fig. 3. Map for Engineering Stages of Product Lifecycle (Adapted from Aca, 2004) in a VO

It is important to mention that since each business opportunity will be developed by one VO, in each stage of the product/process development different partners of the VOs could participate. This mean that, for example, a VO can be configured for a specific Product Design as follows: three partners can participate in the Product Idea definition, and two different partners can develop the Conceptual and Target Specification of the product.

Besides the Product Life Cycle, the VO Life Cycle should be also considered. This means that for the development of a new product in a VO, the VO creation, operation and dissolution phases will be carried out to fulfil the business opportunity. In specific situation, a VO could be configured and dissolved for developing each Product Life Cycle Phase (although this is not a common practice).

3.2 Stage II: Assessment of the AS- IS Model, and Model the TO-BE of the Product-Process Development Process in the VBE.

Figure 4 represents the inputs, outputs, controls and mechanisms of the stage III: Assessment of the AS-IS model, and model the TO-BE of the product-process development process in the VBE.

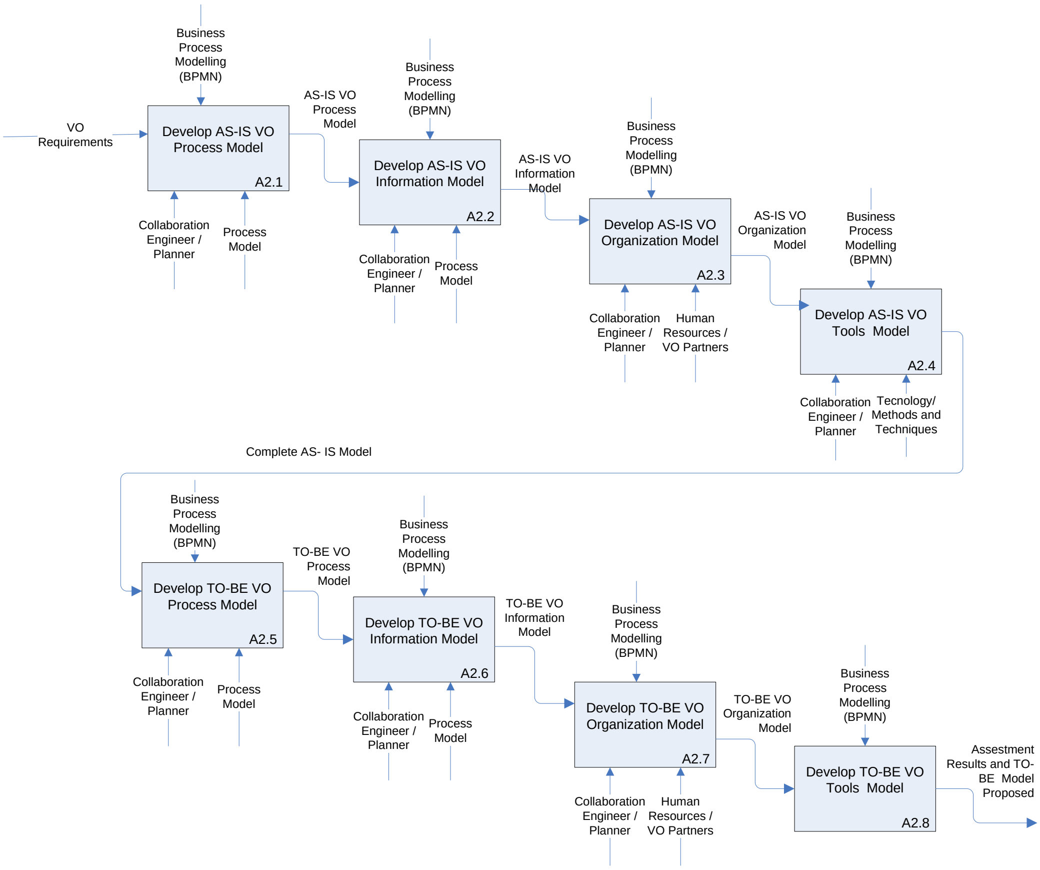

Fig. 4. Assessment of the AS- IS Model, and Model the TO-BE of the Product-Process Development Process in the VBE Modelled in IDEF0

The AS-IS and TO-BE model should be developed based on the VO Requirements identified in previous stage. Two cases can be identified when modelling the Product-Process Development Process: when the VBE has a model defined for product development process, or when this model doesn't exist.

If the VBE has a model for product development that is used when a new business opportunity appears, and consequently a VO is created that follow this model. For this situation the AS-IS model represents how the design process (product or/and process) is currently executed. If necessary, after modelling the AS-IS, the TO-BE process should be modelled, including modifications for improving the process efficiency. The TO-BE model captures the process-redesign for the VO Collaboration Engineering Environment. This TO-BE model will be the base to define the CEE workflows in the following stage.

It is important to analyze the gain in spending substantial effort in modelling the AS-IS process, because in some cases the AS-IS model is fully understood by the company and also are already identified the opportunities to improve it.

In order to efficiently do the models analysis (AS-IS and TO-BE), the use of graphical representations is suggested, which helps to identify duplicated information, parallel activities, and flow of information and material. Four domains must be graphically represented in the model for the identification of the CEE: process, information/knowledge, organisation and resources; the participation of each VO partner should be identified in these domains.

When the AS-IS model doesn't exists, Hepp & Roman (2007) mention that there are large bodies of process specifications known as libraries of best practice that could be used for the TO-BE process; they are an important source of process models for enterprises. Reference process models in ERP packages are also available, these includes standards (e.g. RosettaNet PIPs4) or the MIT Process Handbook (Malone et al, 2003).

Finally, business process model is developed including process model and information flow related with each VO partners. Also, are defined which technologies, methods and techniques can be used to accomplish each activity. There are some standard notations and languages recommended to model business process, such as: IDEF0 (Integrated definition methods), UML (Unified Modelling Language) and more recently BPMN (Business Process Management Notation) (BPMI.org, 2005). Finally, this model will be the input for the design and integration of CEE.

3.3 Stage III. Design and Integration of CEE and its Applications

Figure 5 represents the inputs, outputs, controls and mechanisms of the Stage III: Design and integration of CEE and its applications.

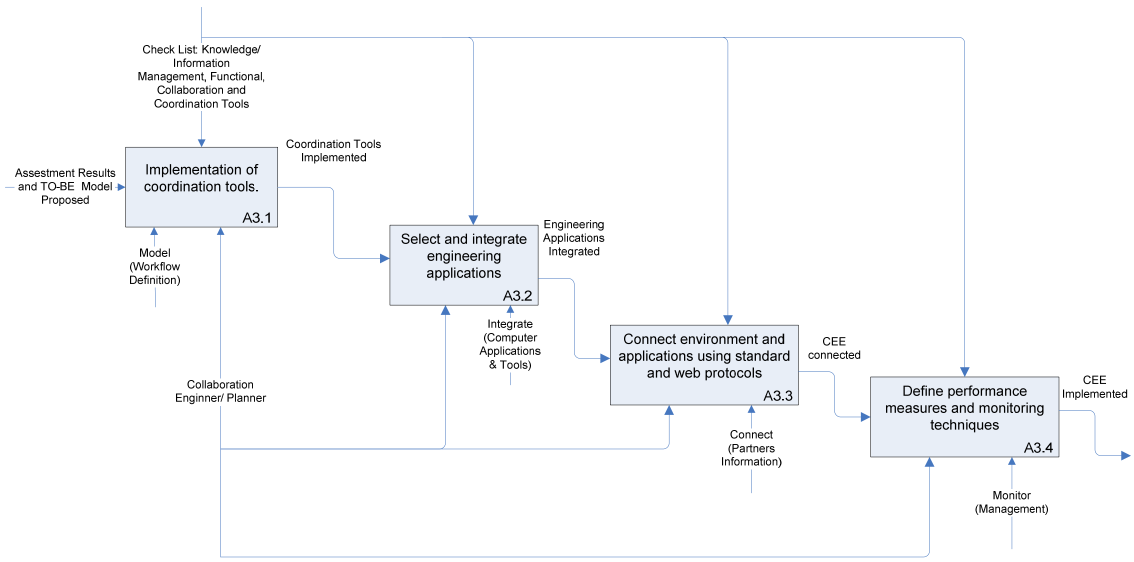

Fig. 5. Design and Integration of CEE and its Applications Stage Modelled in IDEF0

After the AS-IS model is understood (or TO-BE model, if it is the case) four main steps must be followed for integrate the CEE:

Implementation of coordination tools. The coordination tools allow the execution of the whole product development process in a VO and evaluation of the process performance. These tools also help to manage: the activities for the product-process development, the participation of each VO partner in these

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activities, possible problems of information flow, and the core activities and core resources in the VO operation. Project Management applications and workflow systems are examples of this kind of tools.

Select and Integrate engineering applications. Several computer based information systems have been introduced to support IPPFD methodology, which integrates all the activities, methods, information and technologies to conceive the complete Product Life Cycle. Taxonomy for these systems is defined in Table 2 (adapted from Mejía et al., 2006). This table includes a definition of different type of applications that can be used to support different aspects of the life cycle development. The classification includes functional, knowledge/information management, collaboration and coordination tools. For each type of VO the CEE supporting tools used in each category may change, but in general these categories include the tools necessary to enable VO integrated product development supported by CEE. VO partner's competencies should be also evaluated in order to integrate the applications, training and technical support should be provided if it is necessary.

Table 2. Classification of CEE Tools (Adapted from Mejía et al., 2006)

Functional	**Knowledge / Information Management**	**Collaboration**	**Coordination**
To carry out and support specific functions	*To share and manage Information and knowledge*	*To Interact and Communicate*	*To manage and control tasks*
• CAD/CAE/ FEA • Intelligent CAD • QFD/AMEF/ IDEF0 • DFM/DFA • Rapid prototyping • CAPP/CAM • MAS	• Knowledge based engineering systems (KBES) • Product Model • Product Data Management • Manufacturing Model • Knowledge repository • Data mining technique.	• STEP/IGES • Net Meeting • Forums • Multicasting • E-mail • Groupware • CSCW • e-payment	• Project Management • Workflow

Connect environment and applications using standard and web protocols. Two groups of connections can be identified in this process. First group includes marketing information exchange (e.g. Web pages, e-catalogues) and interconnection of Manufacturing / Production information (e.g. e-RFQ, ERP, on-line Capacities). The second group includes the information exchange among VO partner's functional tools (e.g. CAD/CAM/CAE files). Interoperability among different VO partners' application have to be considered during the connection stage.

Web-based manufacturing systems have been developed in the past decade for supporting activities in different product development life-cycle phases (marketing, design, process planning, production, distribution, service). Figure 6 describes a VO manufacturing system infrastructure. The VO management tools are a group of Web-based manufacturing systems located in a Web-platform that can be accessed by any VO member anywhere in the world using Web-tools and Web-browsers. The Web-tools provided to the VO members are the integration of VO member tools in a connect environment known as CEE. The use of a CEE in a VO, focused on product development might increases efficiencies, decreases product development led-time and improves quality through cooperative partners work (VO members).

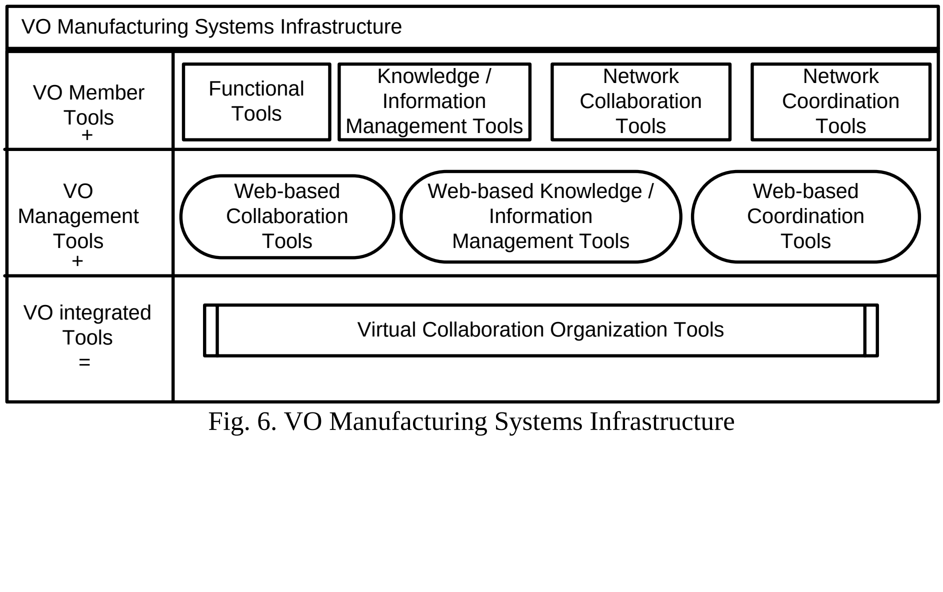

Fig. 6. VO Manufacturing Systems Infrastructure

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Other important concepts in this field, is the use of ontologies and data mining. Ontologies are increasingly seen as a key technology for enabling semantics-driven knowledge processing. Communities establish ontology, or shared conceptual models, to provide a framework for sharing a precise meaning of symbols exchanged during communication (Maedche, 2003). Ontologies provide structured, formal, and unambiguous sets of terms for describing certain domain vocabularies. Ontologies support communication by providing a shared vocabulary with well-defined meanings, thus avoiding ambiguities and misunderstandings (Huang & Yau, 2006), specially between VOs. On the other hand, Data mining is the process of searching and analyzing data in order to find implicit, but potentially useful, information. It involves selecting, exploring and modelling large amounts of data to uncover previously unknown patterns, and ultimately comprehensible information, from large databases. These two concepts can improve the search and retrieval of information among VOs, achieving a same meaning and improving information/knowledge integration.

Define performance measures and monitoring techniques. Measurable parameters and monitoring techniques that allow VO managers to coordinate, track and control the product development process are identified during this phase. The workflow model should have a guideline for associating all the measurable data. This data includes, for example, the VO and partner resources involved in each activity (human and technological), which are important for cost estimations and also for workload analysis. Furthermore, assigned dates and time for each partner are also included to control delays or precedence problems based on unfinished activities. Similarly, activities' input and outputs should be controlled, for manage information flow and availability of further activities.

Finally, in this stage the CEE is implemented. In the next stage is executed and evaluated to develop a continue improvement.

3.4 Stage IV. Model Execution, Evaluation and Inheritance

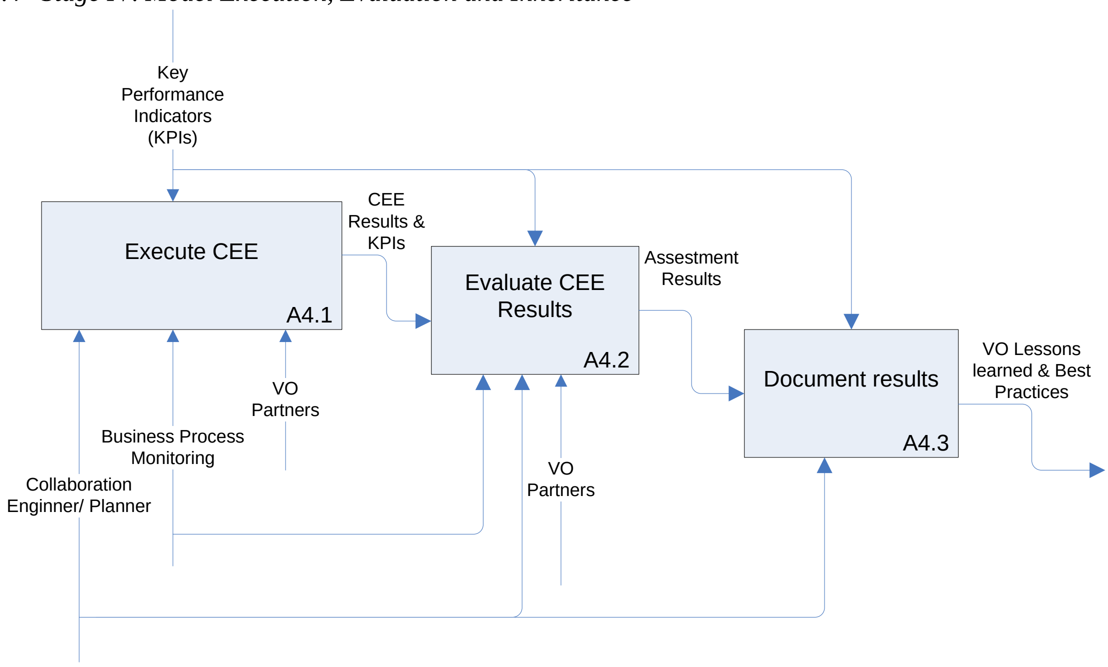

Fig. 7. Model Execution, Evaluation and Inheritance Stage Modelled in IDEF0

The loop for continuous process management is closed by the use of monitoring techniques. It provides external visibility into what is occurring when the product development in the VO is being executed. The process management tracks events and data from the Workflow environment execution and provides both real-time and historical tracking of what is occurring in the workflow engine. Finally an improvement process is performed, in order to analyze a possible new TO-BE model (the current process in execution is converted now in the AS-IS) and maybe new design improvements can be proposed to improve the business process in VBEs. Although this final phase close the loop in the methodology, after the VO is dissolved all the information collected and lessons learned during the product/process development should be transferred to the VBE according to the VO inheritance process. Figure 7 describe all activities that are part of the final VO life cycle stage: Dissolution.

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4. SPECIFIC REQUIREMENTS OF CEE FOR THE CONTEXT OF VIRTUAL ORGANISATIONS

During the definition and evaluation of the CEE methodology the following set of specific requirements for applying the CEE in the context of Virtual Organisations were identified:

- Do not forget that the focus is in a network of organisations and not in a single organisation. This means that: requirements, models, workflows, integration of applications and performance measurement should consider all the partners involved in the VO, its resources, tools and ICT support infrastructure.
- The AS-IS and the TO-BE model should integrate both: the inter-enterprise and the intra-enterprise view. The participation and interaction of each partner in each product/process development stages should be clear modelled.
- CEE should also consider interoperability issues between systems. CEE is used to connect multiple VO partners and clients, which have different technological resources, and this could difficult the connection phase.
- Definition of performance measures should target both: the measurement of the VO itself and the measurement of the participation of each VO partner.
- Due to the nature of the VOs, in the final stage of the methodology the VO dissolution phase should be considered (this phase wasn't included in the original CEE methodology). The inheritance process is an important issue that should be carried out: knowledge should be transferred to the VBE or in some cases to the following VO that will continue the product/process development stage. For example, if a VO is doing the design of a product, the final product design with all its specifications should be transferred to the new VO that will manufacture the product (inheritance process).
- Due to the dynamic nature of VOs, CEE should allow the rapid workflow configuration, according to each business opportunity.

5. CASE STUDY

This case study is developed in IECOS, which is a small company, spin-off at "Tecnológico de Monterrey" and has been developed based on the VO model. The Value Proposition of IECOS is to optimize the performance in "make-to-order and engineering-to-order" business processes based-on an architecture that inherently integrates and improve the relation between customers and partners. IECOS acts as a broker in a VBE (Virtual Breeding environment) enterprises including metalworking, CNC, plastic, finishing processes, welding, painting, logistic, and packing. Thanks to this network, IECOS has the capacity to offer a complete variety of products and processes.

In order to improve integration and collaboration of partners and customer, the CEE-VO methodology was implemented. A product transfer process for IECOS's aerospace customer is analyzed using the methodology described in section 3, results and conclusions of this analysis and implementation are presented below.

5.1 Stage I. Identify IECOS Requirements in the Product Development Reference Model

Using the map for engineering steps in product life cycle, IECOS product development model is composed of individual component specification, manufacturing & control, manufactured components. The components are manufactured by conventional processes and the VO partners selected must fulfil requirements in cost, time and quality. Usually IECOS receive product drawings and customer specification and then, product development process starts with the analysis of the product requirements and the selection of partners inside the VBE. This model presents five stages (see Figure 8):

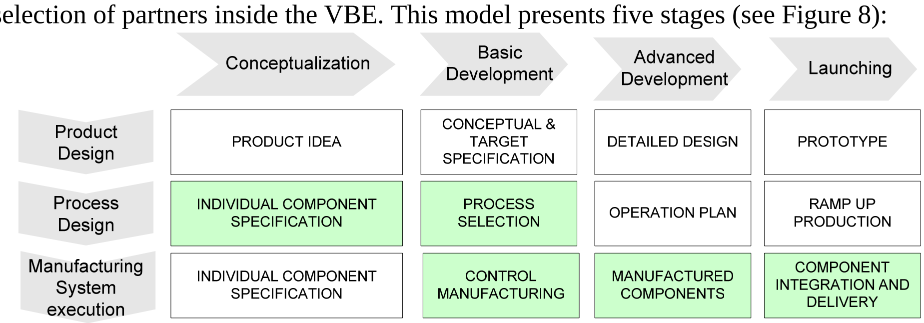

Fig. 8 IECOS Requirements Identification

- Individual Component Specification - product information is identified. The Bill of Materials (BOM) is analyzed in order to identify materials, standard components, quality standards and delivery times according to customer requirements. According to the VO Life Cycle, this process is part of the VO Creation Phase.
- Process Selection - Manufacturing competencies (capacities and capabilities) from different partners are evaluated in order to integrate their competences for develop the project. Suppliers for standard parts are also selected. The VO is then configured; this process is also part of the VO Creation Phase.
- Control Manufacturing - Control variables are defined to be controlled along the manufacturing process. At this moment the VO Operation Phase starts.
- Manufacture the components - Components are manufactured by the VO partners continuing the VO operation phase.
- Integration of Components and Delivery - components are delivered to IECOS; final quality controls are done and documented. Final product is packed and delivered to the customer. This process includes VO Operation and finally the dissolution phase. When the product is delivered, all its related information is transferred to the VBE that in this case is IECOS Company itself.

5.2 Stage II. Assessment of the AS- IS Model, and Model the TO-BE of the VO Operation

As part of the VBE managerial task, IECOS had defined a product transfer process that it is followed each time a customer needs to transfer products to a specific VO (see Figure 9 and 10). IECOS identified the need to build the product transfer information system thinking forward to improve the decentralized information workflow between their clients and partners, as showed in Figure 9 and 10. These figures represent the AS-IS model, were all the information flows through e-mail, fax or sometimes by phone.

For the case represented in the figures, the partners selected have capabilities in machining, welding, heat treatment, painting, packing, and assembly and logistic processes. IECOS execute the logistic, packing and assembly process, and the manufacturing processes are executed by other three VO partners (for simple representation purposes, in Figure 9 and 10, the three VO partners are only represented by one upper lane.

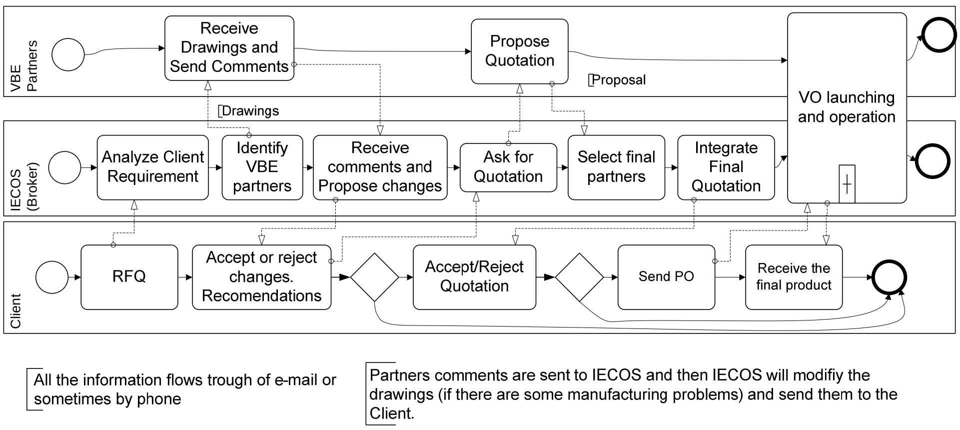

Fig. 9. AS-IS Model for Product Manufacturing Process in IECOS (using BPMN)

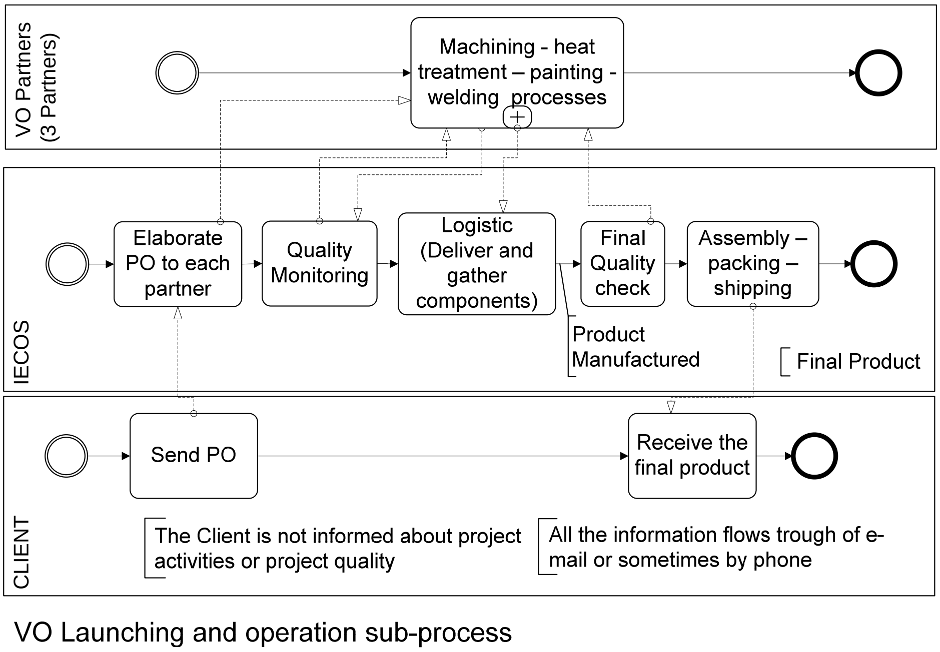

Fig. 10. AS-IS Model for Manufacturing, Quality and Delivery Sub-Process (using BPMN)

IECOS TO-BE model proposes a web-based application that provides to the clients order management capabilities, order status visibility and transaction history. Also, it offers to the VO partners a "quick start" for on-line order fulfilment. With this application IECOS will offers a cost-effective method for support client requirements electronically (see Figure 11). The mayor difference between the AS-IS and TO-BE Model is the quality monitoring and the information flow, which is represented in Figure 12.

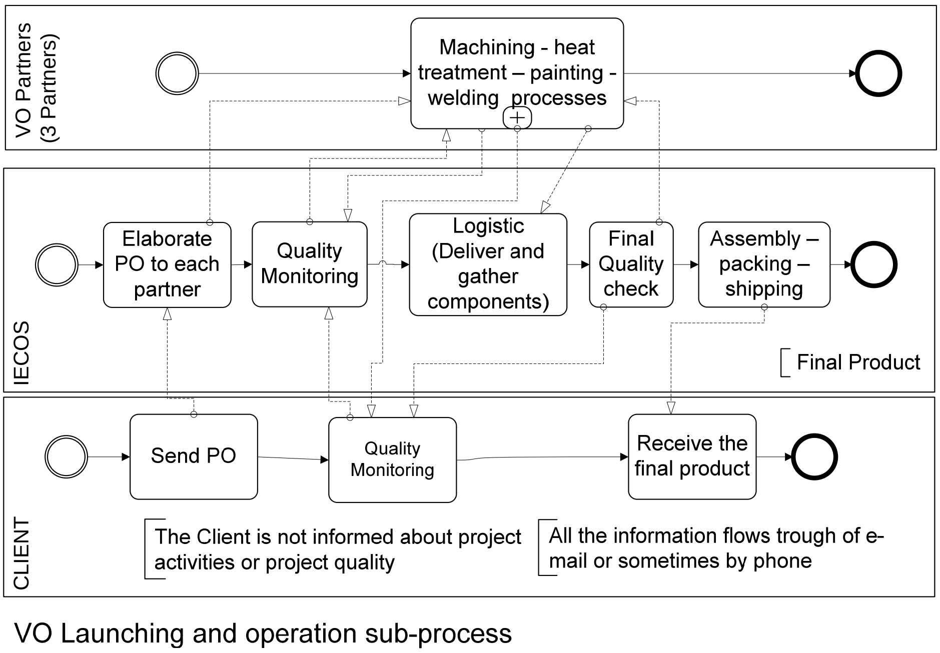

Fig. 11. TO-BE Model for IECOS Manufacturing and Quality Sub-process (using BPMN)

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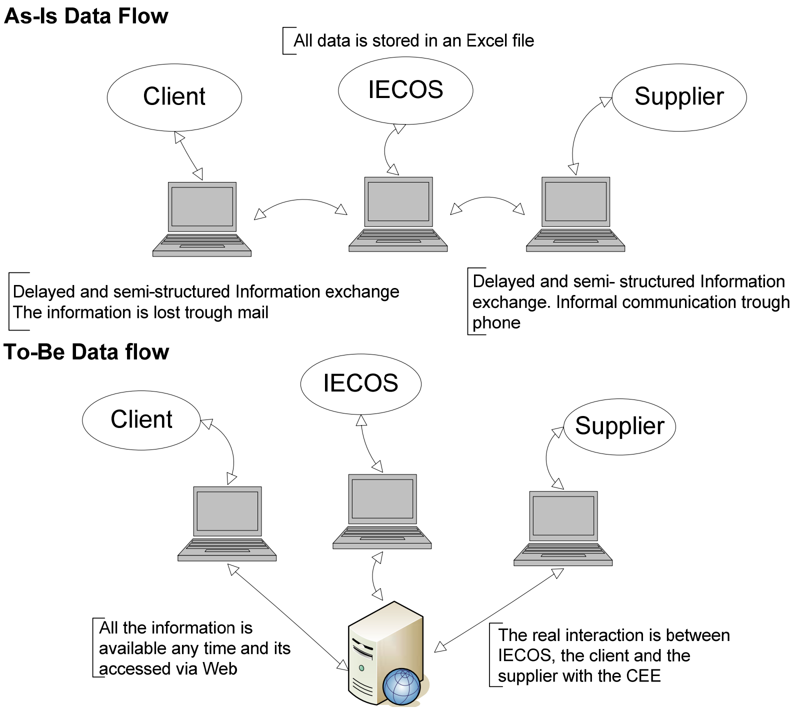

Fig. 12. AS-IS and TO-BE Information flow in IECOS

5.3 Stage III. Design and Integration of CEE and its Application

Model the Workflow: The improved process consists in two main flows (see Figure 11) that includes product manufacturing process as part of the VO launching and operation phases. Quotation activity starts when the client sent a RFQ (request for quotation) to IECOS. After that, IECOS can distribute this project between the specific VBE partners adding in the drawings some technical comments. VBE Partners can download the files needed to make their quotation and also can send questions or comments to IECOS. This comments and questions can be approved by IECOS to be seen by the client or can be used only for the communication between the partners and IECOS. Once the VBE partners have the quotation for the project, they upload it in the CEE and IECOS can see all the quotations made by the different VBE partners and can choose the best one. IECOS will consolidate in the CEE the final quotation for the client, including all components prices, total lead time, and special requirements, a VO is then configured with VBE partners. Then the client can evaluate the quotation and decide if they will send a Purchase Order (PO). When the PO is sent to IECOS, the VO is launched and the manufacture of the pieces starts. IECOS adds the PO information in the CEE indicating to each VO partner the parts that have to be manufactured, finally the VO operation starts.

During manufacturing, the VO partners and IECOS add information about project process, usually for the 25%, 50%, 75% and 100% of the project, so the client knows exactly the real project progress and the activities that were needed to complete the project. Any problem that occurs during manufacturing can be solved using this CEE, making comments or questions. When the project is finished, IECOS includes a photo of the product in the system and client can observe the final product. The client also knows if the product is already sent and when it will be arrive. This CEE also manages the administrative issues of the project so administrative personal can know if the PO is already paid or if it doesn't.

In Figure 10 are presented the different workflows modelled in MQSeries© Workflow's.

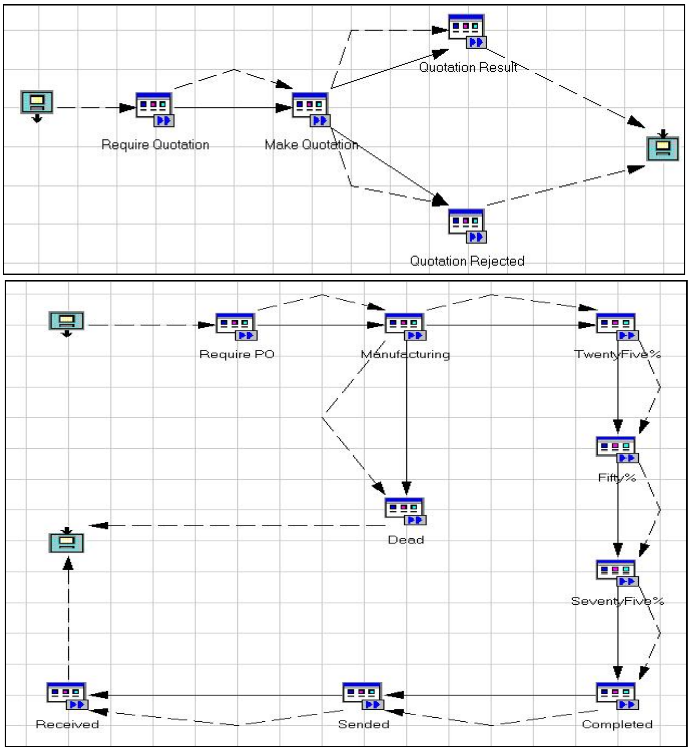

Fig. 13. Quotation and Purchase Order Workflows that Support the TO-BE Business Process Proposed

Selection and integration of engineering applications: The VO members in this project have different tools. VO partners use functional tools (CAD systems), collaboration tools (this tools was based on sharing standards formats such as STEP/IGES) and coordination tools. IECOS has IBM and Dassault Systemes infrastructure to manage the information, using data base management (DB2©), functional tools (CATIA©-DELMIA©), collaboration tools (Quick Place©, Same Time©) and coordination tools (MQSeries© Workflow's).

Connect environment and applications using standard and web protocols. IECOS-CEE was built using IBM Power architecture© and supported on AIX (Advance Interactive eXecutive) Operating System© developed also by IBM based on Unix System. IECOS-CEE includes an IBM WebSphere Application Server© (WAS), built on open standards such as J2EE, XML, and Service Oriented Architecture; and an IBM DB2 DBMS© for management of database-based applications (WebSphere Portal©, Workbench Application©, and Workflow Web Client©). WAS is the host for WebSphere Portal©, which provides a personalized access to a variety of engineering and collaborative applications to IECOS clients and suppliers. Most relevant applications available are a Workbench Application© and Workflow Web Client© that they interpret and process events such as documents submitted to the server (e.g. CAD files) or due dates expiring and act on these events according to the defined business process. The actions may be anything from saving the document in a document management system to issuing new work by sending an e-mail to users or escalating overdue work items to management. These two tasks are supported by Lotus Software division of IBM: 1) QuickPlace© Application supported on Lotus Domino© LDAP (Lightweight Directory Access Protocol) which provides a browser-accessible workspace to support a task or project, and 2) SameTime© Application allowing instant messaging and web conferencing. Finally, communication between different applications and platforms is supported by MQ Server© of IBM, a message oriented middleware that allows independent and potentially non-concurrent applications on a distributed system to communicate each other (http://www-306.ibm.com/software/websphere/).

In the Figure 14, is presented the technology topology, which describes the interactions between technologies and VOs (IECOS, Customer and supplier). The security is supported by the applications selected and was not necessary to develop a sophisticated security system for this case study.

International Journal Information Technology and Management, (2009), Vol. 8, No. 3, pp. 298-320,
DOI: 10.1504/ IJITM.2009.024607, Inderscience Publisher, ISSN: 1461-4111 (Print) 1741-5179 (Online)

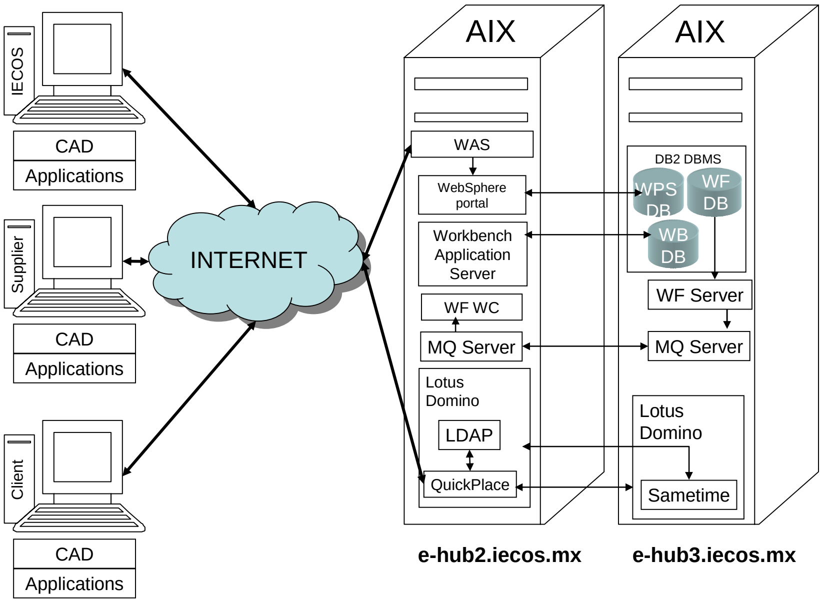

Fig. 14. Application and VO integration (Topology)

Define Performance Measures and Monitoring Techniques: The performance in this process is monitored by the relation between the number of Quoted Projects, Manufactured Projects, Stand-by Projects and “Dead Projects” (projects not executed). Also the system generates some financial statistics such as: relations between projects paid and projects pending to pay. These statistics can be filtered by a range of days, months or years, but also by status (manufacturing, sent, received, and dead) and can be generated for a specific project.

The final design of the CEE will includes the following features: Real-time receipt of electronic purchase orders and change orders; Full visibility to order status and transaction history; Robust customer communications handling including purchase order acknowledgements, change order acknowledgements, advanced shipping notifications; Receipt and sending attachments; On-line ad-hoc queries (ask and response); Secure messaging, translation, and monitoring services guaranteeing 100% transaction accuracy.

5.4 Stage IV. Model execution, evaluation and Inheritance

It was difficult to compare all the indicators defined in this methodology, because IECOS didn’t have at that time any historical data concerning with the indicators defined in the table 1. However, complete time order processing and operative cost could be measured and compared with historical data. Quantitative measures that represent the advantages of the CEE implementation are also identified in the Table 3.

Table 3. Difference between the AS-IS and TO-BE Model

Disadvantages in the AS-IS Model	Advantages in the TO-BE Model
Expensive order fulfilments costs	Reduces in order fulfilments costs (5%)
Need to phone, fax or e-mail order acknowledgements, shipping notifications and other client communications	On-line order client communications and improve shipping notifications.
Delays in processing time of purchase order communications	The purchase order is immediately processed.
Delayed and unclear visibility to order status and order history	Visibility of order status and order history. On time in the lead time.
Limit customer support to existing buyer relationships through order processing	Complete customer support through improved order processing
Limit supply-chain collaboration tools between a supplier and its customers	Additional supply-chain collaboration tools between a VO partners and its customers
Limit value-added customer solutions	Offer strategic value-added to the customer aimed to improve customer loyalty

Due to the nature of the CEE developed for IECOS it could be noticed that all the information regarding a new VO created is automatically stored on the platform, this means that the inheritance process is a transparent process that is supported by the CEE. This help the knowledge transfer of a specific developed VO, in such a way that, when a similar product is needed, the information can be retrieved according to the confidentiality rules (that are previously defined by the VBE manager, the customer and the VO partners).

6. CONCLUSIONS AND LESSONS LEARNED

A methodology for design and implement CEE in VO was presented in this paper. The methodology is based on the CEE methodology proposed by Mejia (2006), and includes different tools for achieve inter/intra-enterprise integration. The four stages of the methodology were focused on the analysis of a collaborative network instead of a single enterprise, and the VO inheritance process was introduced. A set of specific requirements of CEE in the context of Virtual Organisations were also depicted in this research work.

The CEE implemented in the case study principally improves: 1) the VO collaboration and integration; 2) the coordinators of each business opportunity easily manage the project information and; 3) the client was involved during the VO operation, through the actual information of the project status.

IECOS CEE will serve in a nearly future as the base platform for use future supply chain collaboration tools between VO partners and its customers. VO Partners can reduce costs to serve their customer through lower order processing costs and improved customer data. The CEE solution is a market differentiated and value-added customer solution that can be used to create customer loyalty. IECOS CEE can also be used for other VO partners seeking to increase service levels and connectivity with their clients through the creation of a VO, providing an automated supply management options via the Internet.

During the case analyzed some important factors for the implementation of these tools in a VO were identified such as the cultural change and the learning curve. It is very difficult to change the way that some VO partners are used to work. Convince them that using this CEE can improve the collaboration and the information management process is an important task for the success of this implementation. On the other hand, it is important to consider the time to learn and train on these tools. Persons that are going to use this environment should be involved in training courses and also should need continuous support.

This systematic methodology could be extended to any VBE that aims to create VO focused on product manufacturing. However, as part of further research activities, it is important to validate this methodology in other areas, like product design.

Actually, the research team is working in a CEE-VO system that include open-source infrastructure, which can be potentially used by SME.

7. ACKNOWLEDGEMENTS

The research presented in this document is a contribution for the ECOLEAD Project, funded by the European Community, FP6 IP 506958, for the “Rapid Product Realization for Developing Markets Using Emerging Technologies” Research Chair, ITESM, Campus Monterrey, and for the “Technological Innovation” Research Chair, ITESM, Campus Mexico City. The authors wish to acknowledge the support of the Innovation Center in Design and Technology from ITESM - Campus Monterrey and specially the support of the IBM SUR Grant.

This paper is an extended version of the original article published both preprints and post-conferences proceedings in the 12th IFAC Symposium on Information Control Problems in manufacturing (INCOM’06) [Peñaranda, 06].

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