COLLABORATIVE PLANNING OF A MANUFACTURING DESIGN PROJECT THROUGH A NOVEL E-ENGINEERING HUB

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Abstract: Due to globalization of economies, organizations have started a new way of thinking in projects development. New needs arise on working practices as well as supporting Information and Communication Technologies. This article describes a novel concept of an e-engineering HUB for remote collaboration on engineering partnerships. It offers collaborative project planning services that focus on collaborative, tactical decision making that goes into the formation, work planning, contracting and trust building on both sides of an e-engineering partnership. An e-Hub software prototype has been developed and a domain-specific scenario originated in the manufacturing-engineering domain has been evaluated.

Keywords: Business process engineering, Design, Planning, Process models, Concurrent engineering, Co-operation, Co-ordination, Information technology.

1. INTRODUCTION

Globalization of markets has forced companies to distribute their operations. Not only multinational companies are operating in a geographically distributed manner, but also extended and networked enterprises through their value chain integration. This expansion creates a need on engineers that demands more techniques and technologies to aid them in executing their activities, especially in those where they have to interact with geographically remote partners. Is here where information and communication technologies (ICT) are a new option to support distributed operations, enabling the collaboration efforts through the creation of environments to foster e-Engineering partnerships.

Likewise, a need to efficiently integrate engineering services on an ad-hoc basis will increase over the next few years and the need to do this will be most acute in early stages of new product development – in particular in the conceptual and detailed design phases. So the expansion of Internet-based tools has opened new opportunities for collaborative work improvement. This can explain the development of a new generation of tools designed to support this kind of activity: Internet/Web and CSCW (Computer Supported Cooperative Work) in design (Riboulet et al., 2002).

It is now widely recognized that design related decision-making early in the product development lifecycle has greatest impact on the cost and performance of a new product. Ideally key decisions concerning the market for the product, its functionality, and the properties required of the materials employed as well as the cost and manufacturability of the final product should be taken during the conceptual and early detailed-design phases. Unfortunately very few companies are able to achieve this.

Good project preparation provides an opportunity to accelerate teaming and put in place the protocols, processes and procedures that provide the basis for efficient ad-hoc meeting organisation for decision making as well as for the integration of engineering services on an as needed or just-in-time basis. Project planning (PP) and preparation is not something that occurs once at the beginning of the project, but an on-going process that continues throughout all stages of the work and peaks at times when decisions have to be made or when new partners are integrated into the work of the consortium. Good project planning and preparation lays the basis for better execution of a wide range of other tasks of strategic interest to project oriented organizations:

- Program Management,
- Quality and Risk management,
- RTD and Innovation Management,
- Project Process Improvement,
- Team Building,
- Meeting Facilitation,
- Engineering Service Integration,
- Prospecting,
- Project Maintenance and Administration.

According to Shen (2003) an e-Engineering Environment is an automated environment that enables people to collaborate and interact on the development of a new project regardless of their geographic locations and interaction means. Based on this approach, collaborative environments should foster successful global engineering partnerships through the use of ICT. However, groundbreaking work has to be done in creating structured processes to be followed as well as the corresponding enabling technologies.

The European e-HUBs consortium[1], which was funded by the European Commission's IST program in 2002, has developed a web hosted platform for planning e-Engineering projects. The project aimed at a set of web hosted services that enable projects to be efficiently planned through a so-called e-Hub.

2. e-HUBs TECHNOLOGY

As described in the Technical Annex of the e-HUBs Proposal (e-Hubs 2001), the project targeted the conceptual development and implementation of e-Hubs, a novel concept for the realisation of distant co-engineering. A generic conceptual framework was developed and a prototype implementation of the generic concepts was benchmarked in co-engineering processes within the development life cycle and manufacturing process of customized products.

The e-HUBs project has resulted in a first generation prototype with unprecedented project planning functionality (Augenbroe 2004). The prototype has been developed on the substrate of an existing web hosted collaboration platform. The platform offers all the normal functions typically found in a web hosted collaboration space, e.g. community building, team communication manager and document management. The process modelling module operates on the basis of these functions but has two added functional modules: workflow management and project planning. According to Mejía, et al. (2004), a collaborative environment should include four categories of applications: Functional, Coordination, Collaboration and Information/knowledge Management. Table 1 describes the technologies included in the e-Hubs prototype system.

Table 1 e-HUBs prototype's modules

Functional	**Knowledge / Information Management**	**Collaboration**	**Coordination**
Reports: Application for saving workflow data into a document based on Templates	*Files repository:* • Document manager • Templates	• Forums • Meetings • Chat • Calendar • e-mail	• Workflow • Project planning *User manager*: For users administration and role assignment

The prototype's workflow management module offers a Java based workflow modeler with which the process models can be developed offline and uploaded onto the e-Hub (See figure 1). The program used to design the workflows was JaWE - Java Workflow Editor (http://jawe.objectweb.org/) which generates XPDL files that conform to WfMC[2] specifications (Hollingsworth, 1994), based on a neutral process definition language XPDL (WfMC 2002).

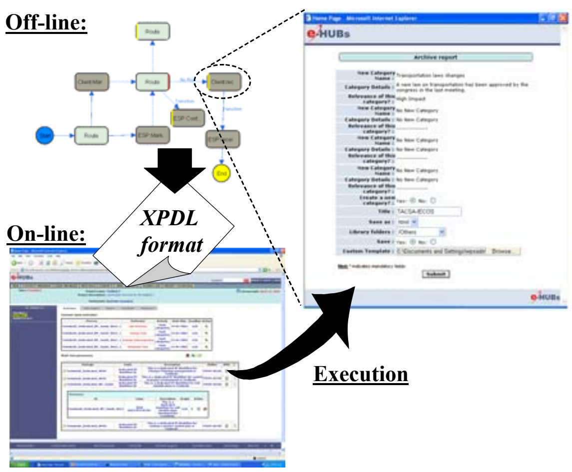

Fig. 1. Workflow design and execution in e-Hubs Web-prototype.

3. PROCESS MODELLING

The service of providing a collaborative platform for engineering projects planning has been identified as a key tool in engineering lifecycle management, extending the capabilities of business partners with joint engineering knowledge and other resources of individual Small and Medium Enterprises (SMEs) by providing brokerage of complementary engineering services. E-engineering tools enable two (or more) parties to support and execute engineering projects through its lifecycle, like the integration of standard

[1] The e-Hubs Consortium consists of: TU Delft (NL), RWTH (GE), Design Solutions (NL), European Dynamics (GR), CKA (BE), GeoDeco (IT), Loughborough University (UK) with affiliated partners ITESM/IECOS (Mexico) and NUMA (Brazil), Georgia Tech (USA) and Penn State (USA)

[2] The Workflow Management Coalition (WfMC) is an international standard organization on Workflow Management Systems (http://wfmc.org/).

applications for collaboration as "Workflow" modelling. This engineering processes modelling provides a new approach to facilitate collaboration by offering transparent templates during the engineering collaboration.

The e-Hub is designed for the tactical level, in planning and negotiation stages, using a generic Project Planning and Negotiation Model (PPM) as main workflow. The existing PPM is based on the work of the PMI (Project Management Institute).

As shown in Figure 2, the tactical collaborations are "directed" by the PPM that was previously defined on strategic level. The end result of the tactical project planning (PP) phase is a project plan, or project management model, consisting of a complete "work statement", including risk assessment, work breakdown structure, schedule, negotiation trail, contract and others. This comprehensive project plan is the operational plan that is delivered to the engineering design team.

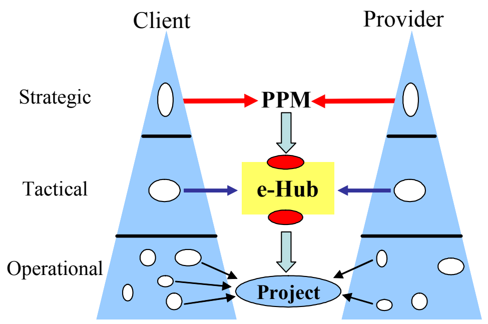

Fig. 2. Strategic tactical operation levels of PP (Augenbroe, 2004)

e-Hubs PP platform, intends to enable parties to transparently produce rich planning information that will exist at the start of execution and will remain a live document through project execution. To achieve this, three topics of the PM work have been developed into three workflows to fulfil these individual topics: (Scope statement (SC), project charter (PC), project execution plan (PE). However, these topics are too generic and some times it is required to create more specific workflows (also called *dedicated workflows* or *supporting documents*) to support a specific domain.

The e-Hubs consortium worked with an industrial scenario (Projects from a manufacturing engineering domain) to implement the e-Hubs system for demonstrating purposes and it required the design and integration of dedicated workflows to support the collaborative project planning in their specific domain (Manufacturing engineering).

It is important to remark that project planning is an activity that relies heavily on human intelligence, acquired skills, experience, creativity and a good sense of people and risk management. The introduction of e-Hubs is not intended to displace, automate or supersede these human expert skills. Instead they will augment them and add new functionality, especially when project planning involves two or more parties that have asymmetric knowledge of the engineering activities that need to be planned, while not sharing the same business objectives in the product development process.

4. PROJECT PLANNING WORKFLOWS DEVELOPMENT

4.1 Methodology

In order to generate a set of supporting documents (dedicated workflows), it was decided to analyse the elements that constitute a good "project plan", and reverse engineer this into a set of communication templates and workflow models that will guarantee the efficient and comprehensive generation of a "rich" project plan. The starting point for this part of the study was the PMBOK[3], together with the analysis if typical engineering scenarios. This led to a generic set of PP processes with general communication templates.

The e-Hubs consortium has followed the next steps (as shown in Figure 3) to achieve a successful design and implementation of dedicated workflows:

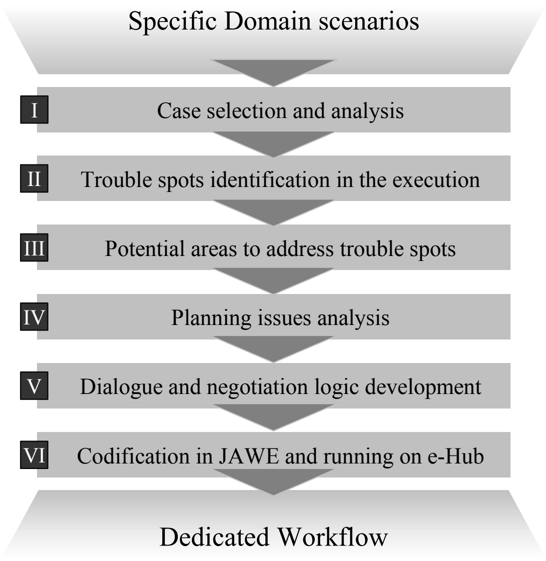

Fig. 3. Dedicated Workflow design methodology.

Step 1: Case selection and analysis
The first step starts with the definition of specific domain, which has to be settled from the beginning (e.g. Civil, Mechanical engineering). All the possible scenarios (kind of projects) within this domain are considered and an overall evaluation of the generic process of each one is carried out (e.g. the different business units within a company). A specific case is selected (a determined project) depending on the level of approaching to the analysis interests. A detailed review and analysis of the PP process is performed, based on its available planning documents and results from actual execution.

[3] A guide to the project management body of knowledge (PMBOK® Guide)

Step 2: Trouble spots identification in the execution
After the specific project is analyzed, the original planning of the project is compared with the real execution. Then, a detailed evaluation is followed comparing each task in order to progressively identify trouble spots and their reasons. These issues will be useful to determine preventive activities in a PP workflow, pursuing the prevention of potential problems during project execution.

Step 3: Potential areas to address trouble spots.
This step aims to select those areas of PP ("planning issues") that could address those trouble spots. The main purpose is to allow workflow designers to define *activities* with potential impact in reducing execution problems. During the negotiation process, those activities will guide Project Planners through important topics to be considered from the beginning (based on experience of previous project).

Step 4: Planning issues analysis
An analysis of these planning issues is performed through brainstorming sessions followed by the development of a "reverse engineered" dialogue that could treat them during project planning. The major output of this step is the generation of the templates and data structures that workflow will manage. This step leads to a set of initial templates designs, as a guide to start structuring a basic set of information to be exchanged in the workflow. Procedures to foresee and overcome such problems during the project preparation phase will be prepared and documented as workflows.

Step 5: Dialogue and negotiation logic development
This step is the main activity in designing the logic of the Workflows. It starts developing a dialogue and negotiation logic, followed by the integration of Templates. A cyclic adaptation of the information templates is constantly performed, due to data structures may vary throughout the workflow development cycle. This step is important, because it considers the interaction among partners, and how information will be exchanged, processed and how decisions are made.

Step 6: Codification in JAWE and running on e-Hub,
As mentioned in section 2 of this article, the e-hub Web prototype is running on the web, integrating different applications for collaboration, coordination and Information management. The most representative task for the prototype functionality has been the Workflows development. At this stage, workflow designers proceed to create the workflow logic, variables, responsible and data structures into the system. Meanwhile, the workflow diagram is also managed by the JaWE tool as XPDL language, which is the information required to be exchanged between the stand-alone workflow modeller (JaWE) and the system on the Web (e-Hubs prototype).

4.2 Workflows Development

e-Hubs consortium developed several scenarios, but authors choose the Manufacturing engineering scenario to be analyzed in this article. An engineering service provider (ESP) in the manufacturing domain was selected as "demonstrator" company. This company has three Business units (*Supply Services, Technology and Construction*) and all of them where analyzed in order to find a potential project to be used for demonstration.

From the Step 1, as described in the methodology, two possible scenarios were identified (considering for this case the Business units of the company, because their projects execution is different). One is the *Supply Services business unit*, but after the analysis, it was found that there is almost no project preparation and few negotiations between partners. In this kind of projects (OEM-suppliers relationships) a price dominant strategies are more considered. Confidential agreements are placed and Purchase Orders plays the role of contracts. In this way, the potential value added of the e-Hubs was low (as it is focused on project preparation). The other potential scenario is in the *Technology Business unit*. Projects within this scenario need more preparation. The execution may vary depending on customer and its needs, offering a wider range for negotiation and preparation of potential projects. Projects of this field are characterized by a higher negotiation and project preparation efforts. Therefore the potential value added of implementing e-Hubs functionalities is higher.

The universe of scenarios was reduced to a manufacturing domain, in a metalworking SME, with a set of specific projects, but finally deciding for one specific project which is the *"Design process of a Dry-Freight Van for Trailer"*.

Afterwards, what workflow designers do was an evaluation session (to perform steps 2 and 3 from the methodology) to find difficulties in the project execution and potentially caused in the project planning phase. According to Step 2, the project was further investigated to detect deviations from the original project schedule and the actual execution, identifying trouble spots. Based on an intermediate Gantt chart and the available project documentation the project activities have been reconstructed. Based on the gathered information the workflow designers identified possible documents which will have to be prepared during the project planning stage. The process followed to determine those supporting documents (specific workflows) for the selected scenario is depicted in figure 4.

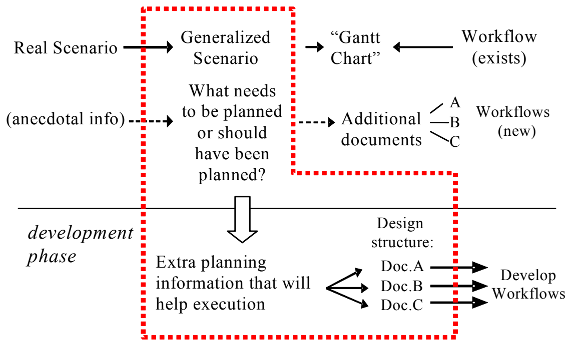

Fig. 4. Supporting documents definition.

As shown in the figure, a generalized scenario is outlined based on real scenario information and supported by a GPPM. Afterwards, specific information from project experts is collected and information structuring is implicitly carried out. Under this approach and with a brainstorming session, a group of information is gathered in order to consider issues that may cause problems during execution and they can be planned (or at least considered) in future project preparation stages.

By continuing with the Step 3, topics like project duration, project design, parties involved as well as changes during execution where discussed, in order to find critical issues to be tackled by new PP activities to address execution problems. With these sketched information, a development phase started, generating a logic of activities and structuring the new supporting documents (specific workflows) that will help execution by minimizing potential problems as they are being considered since early stages of development. For the identified planning information the format has to be defined (in most cases document templates); the resulting planning documents will be aligned with the meaning and terminology of PMBOK concepts, generating the Dedicated Workflows for specific processes.

In the Step 4, those documents were analyzed and proposed in a brainstorming session and finally five templates where generated:

Document A: Environment Control / External factors
In this document were grouped problematic areas detected in execution, creating a set of fields to be considered by the partners from the beginning of the preparation phases. They were called “categories” grouping common difficulty spots as technological, market conditions, regulations, etc.

Document B: Change management control
Most common discrepancies in negotiations are produced by agreements in conflict situations. This document intended to guide project planners in negotiating, from the beginning, a set of conditions for dealing with change requests. The workflow managed a flow of activities working upon a set of variables that would guide partners to a discussion of conditions, until an agreement was reached

Document C: Risk Identification
Usually between two partners, there are several areas considered with a high level of Risk, for example Proficiency, Information Management, Technology, etc. This workflow aims to show user, most commonly risk areas in engineering projects. Partners will asses risks according to their experience, and if a common risk is identified, a set of activities will guide partners to a negotiation process to agree in strategies to prevent or diminish problems in execution.

Document D: Information processing
A very common issue to be tackled and considered by partners in engineering domains is the information transferring. A first problem can arise for example in information exchange from one kind of system to another one (of a different branch or a different version). Additionally, information transferring is a key issue in the globalized market, where this document intends to help partners to negotiate information management systems as internal capacities, or if it shall be subcontracted, or if no complications will be found in information processing.

Document E: Project control plan
This workflow intends to guide negotiators through a definition process of performance measures agreed by parties involved. Likewise, how penalties or awards may be managed as well as management conditions for project execution and all relevant information that strategic levels use to evaluate projects success.

In the Step 5 the design of the logic was performed. A dialogue was developed for each document according to the gathered information. The integration of *Templates* is included being the key component of a workflow design due to the information included in templates can be exported to be further analyzed, or used in other applications or simply to being saved in a document. The Figure 5 exemplifies a generated sketch from the document A to reflect the expected interaction of partners in one specific activity of the whole workflow. This idea was further developed in the system and converted in a web interface with field to be completed by remote users.

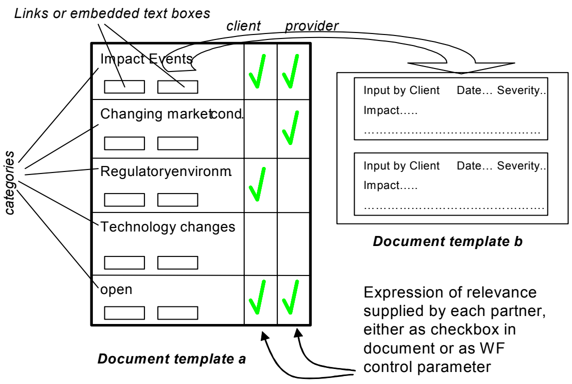

Fig. 5. Example of information structuring sketch.

With this example can be inferred for the logic development that partners have to agree in some concerning areas. If a common area is detected, further steps will continue with other data structure and other activities. If no common area is choose, another set of activities will continue with the corresponding steps to be followed. Finally in the Step 6 the workflows were modelled in the JaWE tool and then imported in the e-hubs prototype to be used, as specified in next sub-section.

4.3 Workflows implementation

When the logic has been understood and all the information is gathered throughout the previous steps, the following stage is to create the model off-line with the Workflow editor (JaWE).

Figure 6 shows the workflow design and its equivalence in the XPDL language, automatically generated by the JaWE which conform to specifications.

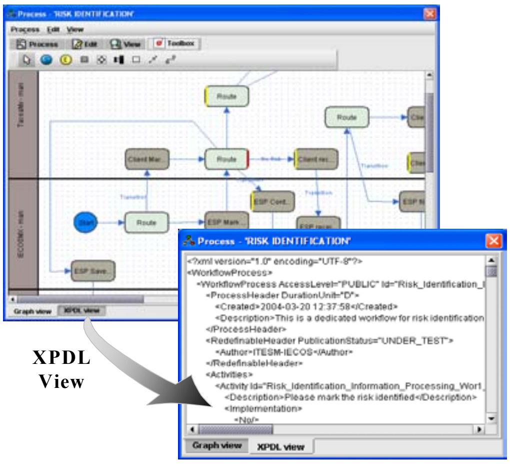

Fig. 6. Workflow design and codification in JAWE.

This XPDL file is uploaded to the e-Hubs prototype system and it is ready for execution (as previously shown in Figure 1). The e-Hubs prototype is accessible to partners involved through Internet (http://elf.eurodyn.com:8080/edos/index.do) by mean of a log-in page in order to access the specific workflows assigned to each project.

The workflows were benchmarked and assessed by the companies involved, running a real need of "information Risk" in the exchange of CAD formats. This time a third party was also involved, in order to evaluate the risk of formats exchange in the Dry-Freight van design. The ESP, the client, and the information technology (IT) consultant (third party) are distributed in Mexico and Europe. The workflow was configured with a pre-defined format by the IT service provider to gather some information of both parties (client and provider) in order to asses the risk, and plan together a potential need of outsource the Product Data Management service for the design process of the Dry-Freight Van for Trailer.

Finally, the ESP's strategy is increasingly oriented to doing business outside of Mexico, creating a need for embedded applications for collaboration. The result is the e-HUB can be used as a portal for information (main public page) and as an enabling technology for interaction with selected customers and providers as well as allied Clusters. The company intends to continue working with these technologies of collaborative business process management.

5. CONCLUSIONS

The experiences with e-Hubs scenarios has contributed by showing the importance of using Business Process Management Systems (BPMS) for supporting engineering processes. This approach has open a new way of thinking in the remote planning of projects by managing workflow concepts for the *Engineering Processes* in industry. As a matter of fact, the e-Hubs concept is generic itself. That means, it can be extended not only for project planning but also for almost all stages of Products Life cycle, where a process or methodology can be defined and structured in order to be followed.

However, more technological improvements to the tool are needed. A next generation of the e-Hubs system should be the next step, because prototypes create human and organizational barriers for the industrial acceptance of technology. Likewise, the introduction of e-Hubs is not intended to displace, automate or supersede the human expert skills. It intends to enhance the remote operation of companies. It is also an additional tool, trying to minimize, but not avoid the traditional communication techniques (e.g. face-to-face, telephone). However, its implementation implies not only the knowledge to use it, but also cultural barriers should be considered. Additionally, the workflows creation is not a simple task. It usually requires a "workflow engineer" to structure and formalize "business processes". Several difficulties are found when the same experts or people involved in the process tries to perform a "process understanding and organization" by themselves.

6. ACKNOWLEDGMENTS

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