Concept for Quality Control Management Services in distributed design networks – Conceptual paper

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Abstract. The actual situation is that partners in virtual organisations rely upon a great variety of tools, which are not integrated, difficult to use and often ineffective. High costs are sustained to train the people and acquire tools of different make as required by the OEMs. The objective of the proposed paper is to present a conceptual model of an integrated engineering environment specifically tailored to the needs of the suppliers operating in a design network. The focal point is to show how monitoring and control of projects in virtual organisations can be supported. Therefore a Quality Control Management (QCM) concept will be presented that is able to provide several services in order to trace and control project processes and performance in an effective, integrated, easy to understand and user-friendly way. The approach presented in the proposed paper is basing on the work carried out by the European funded research project E4 (Extended Enterprise management in enlarged Europe - EC Contract No. IST-FP6-027282).

1 Introduction

The continuous global and local economic fluctuations have increased the stress on manufacturing businesses. Companies' processes are challenged to provide operationally excellent, lean, cost-effective and rapid delivery of products and services globally. As a result of changed manufacturing businesses, companies must take business co-operation (Camarinha-Matos et. al., 2005). Facing a competitive global market, industrial manufacturers are hard pressed to adopt some strategies and technologies to enhance product quality, to cut manufacturing cost, and to reduce product lead-time. Of these strategies, agile manufacturing is being paid an increasingly important attention (Sheridan, 1993). In an agile manufacturing system, virtual organisations (VO) are one of the most important organisation manners (Reid et. al., 1996). In the context of emerging technologies and related knowledge-economy business models, linking stakeholders in dynamic clusters is believed to enhance competition and regional innovation (OECD, 1999).

International co-operation is also a vital strategy for the European companies in order to boost their competitiveness in the enlarged Internal Market and beyond. In all domains concerned with assembled products, the design is by now carried out by a network of enterprises (virtual organisations) (Müller et. al., 2006) which take responsibility of subsystems at the higher tier, and of simpler components at the lower tier. In such a context virtual organisations compete, as usual, on cost, quality and response time, whereby transparency and reliability are key components of process quality. The method presented in this paper is specifically addressing these needs targeting virtual organisations which operate in the product development/ engineering area. From this point of view Quality Control Management (QCM) method provides several services in order to support project and network managers in virtual organisations tracing and monitoring engineering processes during manufacturing projects. The idea behind this method is to trace progress of work and to monitor also performance of project processes concerning several indicators like for example cost, time, resources, risks and other engineering critical issues (Aichele, 1997). Further on QCM supports the re-use of knowledge, experience and solutions gained as a result of tracing and monitoring and it provides this information for future projects. The method followed, QCM is an approach which is able to encompass stages of collaboration (initiation, management, operational life and dissolution) and also phases of extended products' development (conception, design, prototyping). The objective is to provide standardised, effective, easy to understand and low cost services to support project quality management for small partners in collaborations as they rely upon a great variety of tools, which are not integrated, difficult to use and perhaps even ineffective.

2 Quality Control Management Services

ISO9001 standard and Vision 2000 promote the adoption of a process-oriented approach in the development, use and improvement of the effectiveness of the quality management system, to increase the customer satisfaction by fully satisfying the customer requirements (ISO 9001:2000). As the approach of this paper traces the planning and execution of micro-processes the Quality Control Management builds on:

1. the list of project deliverables, linked to the person in charge and due date
2. user requirement on product performances, process quality and production costs

3. Traceability of the development process as the project plan is split up in micro-processes. Each micro-process will contain, moreover, all provided inputs and required outputs
4. KPIs on project costs and risks
5. data access history

Although current project management products prove very useful during project set up, they might prove not so useful when dealing with monitoring the progress of work. Data to calculate key performance indicators, which highlight the real progress of work, is rarely provided as well as the management of input/output deliverables of each phase (Böhnert, 1999). The Quality Control Management method tries to pursue a more comprehensive and integrated approach, where the user – either the customer, the project manager or specific development activity owner – gets all information to plan development activities and monitor the progress of work, keeping under control cost, time, quality and engineering critical issues, to deploy the activities internally and to view all relevant data at different levels of details.
The module provides three major functions:

- Deployment of planned activities with pre-defined micro-processes
- Monitoring capabilities over process and engineering performances indicators
- Levels of detail to represent information

Three levels of representation are envisioned to provide the different users with the proper level of detail, according to his/her role. Each level depicts a view of the project under development for different chores and with a varying degree of detail, from the "Negotiation level" where the customer and project manager agree on results, their deadlines and the path from one result to the next; to the "Deployment level" where each "tract" (part of the path) that will be travelled to get a certain result is split up in the micro-processes necessary to produce the result; to the "Execution level" where attributes of the micro-process must be computed and filled in. In this scenario several user profiles are working together on the same project, all are working to build the product. More project "dimension" are present a time: development, testing, prototypes building (virtual and physical), production scheduling, production tools and plants allocation, delivery, … and also time and costs. Quality target will be deployed in each of these dimensions. Only a taxonomical approach is able to manage a complex product project. Quality means that user target value (= vital parameters on the product) will be reached. Constant control of actual parameters respect the target value is necessary. The challenge is to obtain a dashboard with some KPI that permit to the project manager be able to respond a question like "is the project on time? Is it on cost?"

Approach

In QCM process control and monitoring is achieved thanks to an approach based upon a library of micro-processes, VCOR as process reference model and key performance indicators (KPI) which drive the steps and specify the required resources. The foundation provided by the process reference model and the KPI library allows the monitoring and quality evaluation of all parts of the project.

However it does not provide a complete way to monitor and evaluate the whole project. The missing linkage between single parts is the flow of goods/ information. Thus, focusing on such an approach it is important to realise a linkage between a product and the relevant engineering processes which are related to it in order to produce the required product. To fill those gaps, QCM uses the underlying bill of material (BOM) of the product to be produced in order to determine the links between the project partners and to create a project specific process chain as well as to derive a project plan (see figure 1).

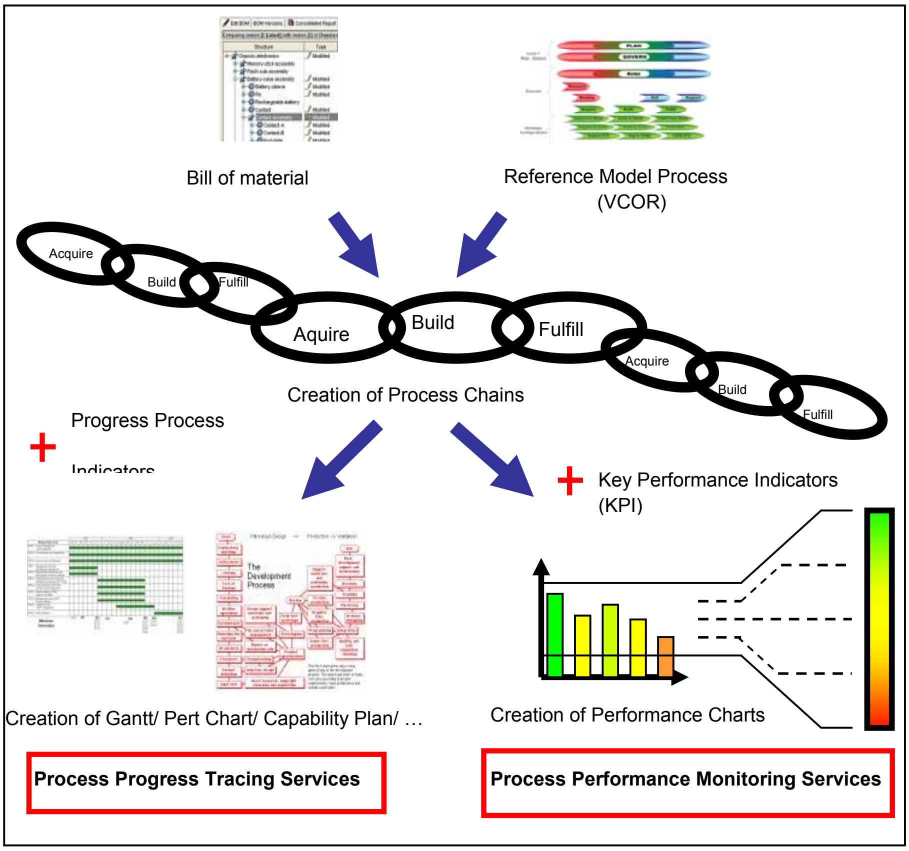

Fig. 1. Quality Control Management Services Approach (following Seifert, Eschenbächer, Thoben, 2004)

The idea to this approach is traced back to the fact that a BOM often turn out to be an initial point of a manufacturing project. It is a formally structured list for an object which lists all the component parts of the object with the name, reference number, quantity, and unit of measure of each component. A bill of material can only refer to a quantity greater than or equal to one of an object. It is a product data structure, which captures the end products, its assemblies, their quantities and relationships. QCM uses this product structure and relationships in order to generate engineering processes on which tracing and quality monitoring services are provided. The product structure shows the material, component parts subassemblies and other items in a hierarchical structure that represents the grouping of items on an assembly drawing or the grouping of items that come together at a stage in the manufacturing process. Further on it provides the understanding of the components which compose a product as well as their attributes.

This method is supported by the participating companies in a virtual organisation, who provide the required information by linking their products to the involved processes. The resulting ability, to identify all processes that are of relevance for the project in combination with having a database that provides information about who can provide the required process, allows QCM to generate highly customizable project partner configurations and at the end customer related services.

Global Process Reference Model (VCOR)
As already mentioned the process reference model is one part of the method. QCM uses VCOR due to a hierarchical description of processes as standards often simplify holistic approaches. To generally enable the monitoring of a project's quality, a method is needed to generalise a project and to transform it into a process based model. To support this modelling for each participating partner of any kind of projects, a generic process reference model should be integrated in the tool, which allows the description of any contribution to a project on a process basis. It is crucial to consider also service and design processes in the reference model.

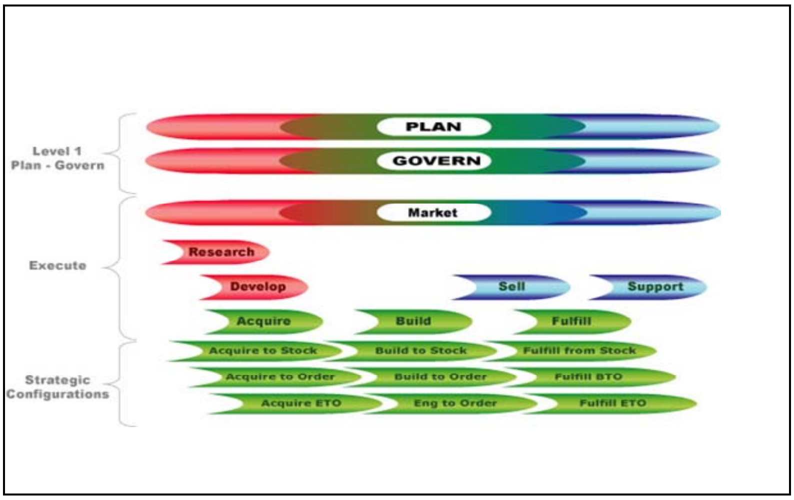

Fig. 2. VCOR model (www.value-chain.org)

Therefore it is foreseen to base the model on an existing standard as the VCOR (value chain operations reference model) which is more service oriented than manufacturing driven. The VCOR model supports the key issues and the gearing together of processes within and between the individual units of chains (networks, virtual organisations) for the benefit of the following

- Planning
- Governing
- Execution (information – financial – physical flows)

with the objective to increase the performance of the total chain (network, virtual organisation) and support the ongoing evolution. Figure 2 presents how VCOR, on executive level, is covering the whole value chain (Research→Develop→Acquire→Build→Sell→Fulfill→Support). The user will be able to input all his information regarding his own processes and at the end QCM generates charts in order to trace and control these processes.

QCM Module Architecture

QCM is embedded in a set of modules, each providing essential functionality supporting QCM (figure 3). The Collaborative Program Management module (CPM) as one of these appropriates a library of micro-processes which enables the QCM to deploy new products out of pre-defined micro-processes. Furthermore CPM puts QCM in a position to offer different levels of views. Doing so it is possible to focus to the execution level or summarise micro-processes and processes and have a view regarding only to results, their deadlines and the path from one result to the next.

Via the Product Structure Management module (PSM) it is possible to load and store files related to the project and to extract relevant information. For instance QCM needs to set up a new product. In this case, the latest existing CAD file can be loaded out of the repository and it is possible to generate a first coarse structure of the BOM out of this data.

A third module QCM interacts with is the Collaborative Knowledge Management module (CKM). This module supplies with information about “goodness” of any process that is traced and monitored by the QCM. Doing so it is possible to evaluate if a considered process fulfilled the expectations or not and why. The data that is evaluated here can be re-used by the CKM in other projects to compare the actual performance with stored data of similar products and their processes.

To ensure that the QCM module can interact with the other modules and use the information provided by them all modules are connected to a SQL relational database using ODBC or JDBC depending on the fact in which language they have been programmed. Moreover the approach of using a data base as data store allows it to exchange information with affiliated software like ERP- or PDM-systems in an easy way. QCM itself is written in the scripting language php to ensure that the module will be platform independent. Furthermore it is possible to set it up as a

service reachable over Intra- or Internet using web technologies (http). No client or special software must be installed in order to use it.
Functionalities of the module and code regarding to the GUI, which is also provided, is separated as clear as possible to make it easy to reuse the implemented methods and GUI elements and to prevent redundant code. In this way it is also possible to generate web services and for instance automatically collect relevant performance indicators or other information by triggering data collection from connected ERP-systems. To do so the implemented methods provide functionalities to generate XML code interoperable to the WSDL standard. The GUI of the QCMS is designed to meet the highest requirements of user-friendliness. The other modules are integrated seamless and guarantee a smooth workflow.
Additional to the mentioned modules QCM reverts to common services and an enabling framework. These services provide functionalities like user management, access control or methods to generate web services and are sourced out to be available for all modules. This ensures the fact that functionalities do not have to be developed from scratch for each module. QCM itself is subdivided into four sub modules: QCM-Global, QCM-Process Progress Tracing, QCM-Process Performance Control and Lessons Learned (see figure 3)

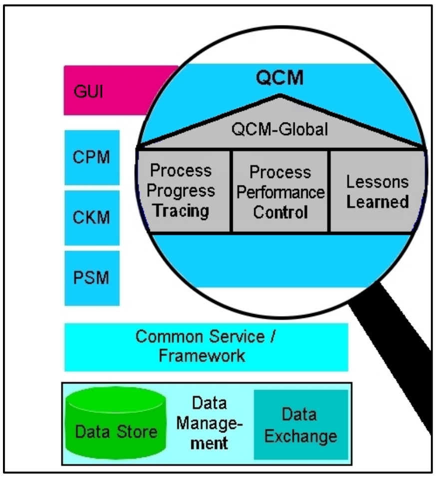

Fig. 3. Module Architecture

QCM-Global

In the very early phases of new product design, engineers begin the design by sketching out a structure for the product which identifies the major components and systems that will combine to create the desired product. For each component, existing standard parts and previously designed custom parts must be evaluated for their ability to provide the necessary function. In those cases for which no existing alternative can be identified, the engineer must specify that new parts should be created, and the details of the structure begin to emerge. QCM-Global, as a sub module of QCM, is devoted to functionalities in terms of building up the structure of a product and adapt it to the process reference model in order to customise a specific product (or project) oriented process chain. QCM enables each partner to define and model the own engineering processes, which are being supported by his company based on such global available process reference model. These single parts of a process chain from each partner can be connected to generate a project wide model with the ability to refine or to aggregate the view. While the network manager will get a top view of the network-wide activities, a process owner within a company will be able to have a detailed look into his processes.

As a first step QCM has to be customised in terms of a selected product which has to be manufactured (VCOR:"fulfilled") by using partner's capabilities that are organised in a virtual organisations. Therefore a network or project manager modifies the VCOR reference model by choosing relevant process out of the holistic VCOR (see figure 2) in regard to a special product's BOM. The result and approach of following scenario is presented in figure 4.

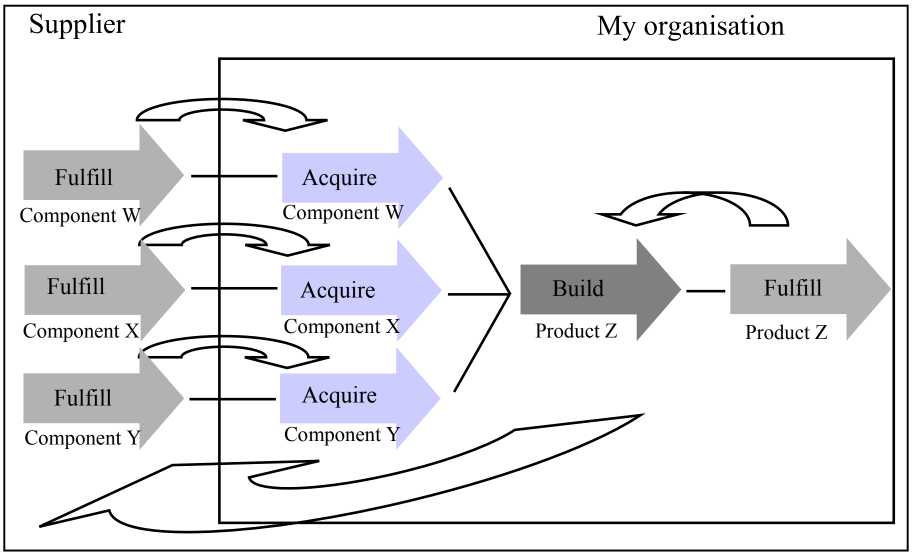

Fig. 4. Module Architecture

Due to own organisation, the network manger has the possibility to select those "acquire", "build" and "fulfill" (see chapter VCOR) process that are relevant regarding the chosen product. QCMS works top down, that means the modification starts at Level 1 and becomes more and more detailed down to strategic configurations. The next step is, regarding the chosen product, to identify all necessary components out of BOM and connect them to the already modified and customised reference model. Depending on the organisation some components are allocated to "build" others to "acquire" processes similarly to well known "make or buy" decisions. For this purpose a library provides all information concerning needed components. In case of missing components a manager is able to edit new one with all engineering descriptions needed and send a request to partners of a virtual organisation. All interested partners receive a message concerning a new "unverified component" and they are in the position to answer the request with all needed information like type of fulfill process (that automatically determines the acquire process of the virtual organisation manager), price and duration to deliver that component (or changing the view to the virtual organisation manager: duration of the "acquire" process). Starting from components allocated to "build" processes the manager also can send requests within his own organisation and ask for duration, costs and resources. These data are called progress process indicators (PPI). As soon as all relevant and required information about all needed components are available QCM creates a value chain at configuration level. Once QCM-Global is modified and configured it posses all process information needed in order to act as a basis for following trace and quality control services.

QCM-Process Progress Tracing

Based on the generated value chain QCM is now able provide Quality Control Management Services for virtual organisation partners who are part of that value chain. The Project Progress Tracing sub module is dedicated to generate and present charts out of available process progress information, like for example Pert-, Gant- and Capacity Charts. Further on each virtual organisation partner can trace costs, time and resources in terms of a specific date or a period. Depending on the role in the virtual organisation the manager has got a holistic view; a special process owner's view is limited to his field of activity or responsibility. There is also the possibility to connect information about costs etc. with selected "acquire, build and fulfill" processes. Progress process indicators (time, cost, resources) are computed from planned data, progress data and their difference; for example it is possible to monitor a project budget, the cumulated real expenditure and their balance over timeSo at the end QCM provides very detailed information about progress of engineering processes in virtual organisations and can give recommendations or warnings concerning any kind of course deviations.

QCM-Process Performance Control

The generated value chain does not only provide the idea to trace processes but also to monitor and evaluate quality based on the performance data of the involved processes. Management of key performance indicators (KPI) allows monitoring both process performance – such as time, costs, quality and risk (PPI) – as well as engineering performance – such as weight, stiffness and costs. Engineering indicators (for example weight, stiffness etc.) are computed from engineering outputs and are used as such or inside other formulas to build synthetic indicators. Some figures like "hours worked vs. hours billed" or "offers vs. realised offers per key account manager" are standard KPIs. The Project Quality Monitoring sub module supports the creation, modification, deletion and search of relevant key performance indicators. Further on it uses a method for acquisition of performance data for configured processes and to select and enter relevant KPIs out of an existing pool regarding selected processes. Using indicators QCM is able to evaluate processes in virtual organisations and visualise performance data in value chains.

Lessons Learned

Knowledge Management is becoming more and more important for achieving sustainable business success. Companies have started initiatives to be able to meet the challenges of the dynamic markets. Many Knowledge Management (KM) ideas like approaches or continuous learning are also fundamental ideas of Quality Management. The management of processes by which knowledge is created and applied is one of the main aspects. Information and experiences must be classified regarding indicators which are provided process improvement (Quintas et. al., 1997). From a QM perspective, an ideal model for evaluating KM should contain following elements, focus on processes, provide information for future activities/ projects, continuous learning and improvement and measurement and standardisation Wilson et. al., 1999).

Regarding Process Progress Tracing and Process Performance Control sub modules there is a lot of interesting information about process progress and performance that can be very fruitful for future projects. Focusing on this idea it makes sense to store project-oriented records like practices, targets, performance, arise unfeasibility a reactive alternatives. So QCM also provides information about good and bad case practices in virtual organisations in order to support re-use of knowledge, solutions and gained experience. The lessons learned sub module prepares all useful information concerning progress and performance that has been generated by QCM and provides it to the global Collaborative Knowledge Management module (CKM). Thus, there is a very close interaction between Lessons Learned and CKM.

3 Conclusions/ Outlook

It has been shown that tracing and monitoring of highly distributed processes in virtual organisations depends on the availability of production data from different perspectives such as design, planning and control or budgeting. The presented QCM functionalities will be implemented into a web-based platform to enable the single actor in the virtual organisation to access and to submit his own data. Integrating the data along the value chain and from different organisations allows the provision of new services to better manage the operations of SMEs in virtual organisations.

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