Paper Submission

Business Process Oriented Information Management: Conceptual Models at Work[1]

P. Peters (Contact author), P. Szczurko, M. Jarke
Informatik V, RWTH Aachen, Ahornstr. 55, 52056 Aachen, Germany
email: {peters,szczurko}@informatik.rwth-aachen.de
Phone/Fax: +49 241 8021521/ +49 241 8888321

M. Jeusfeld
University of Science and Technology, ISMT, Kowloon, Hong Kong
email: jeusfeld@usthk.ust.hk

Abstract:

The reorganization of function-oriented, hierachically structured firms into interacting business process networks of functional islands integrated by flow of material and information is a major challenge for a company that wants to meet the steadily changing business demands of today. As information has become an important production resource during the last decades, the reorganization of information management has to accompany organizational restructuring. In this paper we propose a partially decentralized and business process oriented information management approach for quality management processes. We will describe how conceptual modeling of those processes supports the information system design within this approach and how the described models facilitate information management tasks within the given architecture.

Keywords: Information Management, Information Evolution, Repository, Meta Modeling, Business Process Design, Distributed Information Systems,

[1] This work was supported by the German Ministry of Research and Technology under grant 02QF3004/1, by the German Research Society's Graduate College 'Computer Science and Technology' at RWTH Aachen and by the European Community under Information Systems Interoperability Project No ECAUS003.

1 Information Management in Distributed Environments

In order to improve business processes, the organization of industrial work is in the midst of transformation. Functionally divided, vertically integrated and hierarchically organized firms give way to process networks of islands integrated by flows of material and information ([4], [11], [27]). The interplay of ideas from Organizational Theory on one hand and the technological development in information science on the other established the ideal of the 'flexible corporation' that meets customers' needs, makes effective use of assets and is able to adapt to new ways of working or changing business demands ([14], [23], [24]).

Computer networks and task oriented access to information distributed over the functional islands are the technological backbone of these flexible corporations ([1], [18], [25]). Therefore, distributed or federated databases are a more and more accepted means to integrate information sources over the whole company and to facilitate information storage and access ([2], [3]). Though this technological solution provides one necessary precondition to a process-oriented organization structure, there are still many problems to solve. In the following we want to focus on several problems from the information management viewpoint:

1. *How to integrate distributed information sources conceptually?*

   The ideas proposed in the literature range from an integrated information descriptions using standards or company-wide data dictionaries to fully federated systems where all sources provide interfaces to outside users [16]. In recent years, the repository approach for the conceptual integration of distributed applications becomes more popular in the business process reengineering context, because it allows to model the relations between information and the environment in which it is used at various levels of abstraction (see e.g. [5], [6], [15], [28]).

2. *How to get the right information at the right time to the right place?*

   Information is just a means to support effective and efficient action of the responsible persons and teams along the process chain [12]. The automation and facilitation of data production and the higher availability of information often lead to information overload causing just the opposite. Concepts of lean and adequate information management have been developed in recent years (see, e.g. [8], [10]). Though they have influenced data modeling or led to economical buzzwords like downsizing or outsourcing, with respect to business process oriented information distribution and access these concepts are rarely implemented today.

3. *How to manage change?*

   Automated solutions tend to freeze the organizational state because they support given work structures and often make process changes more costly and lengthy ([25], [27]). But in an environment of steady changes the ability of fast adaptation to new requirements is a major competitive advantage.

Standing in the middle of research, we are not able to provide complete answers to all those questions, but in the following we will show that conceptual models of business processes and information needs are helpful in various ways. Beyond being used for the specification of data and systems, we describe how they help solving problems related to the above questions if they are embedded in the developed information system architecture.

We will start with a description of the repository-based federated information system architecture developed during the WibQuS-Project[2] which deals with the integration of quality management methods along the product life cycle in manufacturing. After reviewing the impact of conceptual modeling on the method integration task, we will

[2] WibQuS is the German abbreviation for ‘Knowledge-Based Systems in Quality Management’.

list several every-day information management tasks and how they are supported by the described architecture. Based on our experiences in WibQuS we will describe a pattern of 'information evolution' in distributed environments and will explain how this pattern influences information management tasks.

2 The Trader Architecture

The goal of the Germany-wide WibQuS-project is the interoperation of quality management methods at all stages of the product life cycle from design tasks supported by Quality Function Deployment (QFD) to support methods and tools for service engineers ([15], [20]). Quality management processes are of special interest in information management because information flows occur in various types (data, knowledge, strategy) between differing method executing agents (automated systems, engineers, teams) . The transfer of product and process information not only follows the product life cycle (c.f. fig. 1), but it's crucial also along multiple control cycles from the manufacturing floors back to work preparation and product planning. The usage of this kind of organizational knowledge is a necessary precondition in any effort for better product and process quality and for fast adaptation to changing demands, laws, and customer's wishes [22].

The information system development in the WibQuS project is based on a repository approach. It was started with a conceptual modeling phase, where all engineering teams located at seven research institutes in four cities had to develop a model of their method by instantiating the meta model depicted at figure 1 (the topmost level of the repository). This time consuming process, facilitated by the client-server architecture of the conceptual modeling tool ConceptBase [13], was performed mainly for two reasons, related to questions one and two in the introduction[3]:

[3] A more detailed description of the distributed modeling process, which is in itself quiet interesting with respect to information management aspects is given in [20] and [21].

1. To first facilitate interoperation between the locally as well as conceptually isolated tasks and methods by a common language (the conceptual model) and then relate them semantically by detecting information needs and sources that connect the methods and serve as a starting point for information modeling on a more detailed level.
2. To explicitly relate information to the tasks where it is needed and to the agents that perform the tasks (see also [17]). This way the needs, skills and responsibilities of agents in a specific decision process can be taken into consideration explicitly which is a first step to 'task and decision process oriented' information management.

The modeling process ended in an 500 object model of quality management methods (MQM) at level 2 of the repository shown in figure 1. This model is a central element of the WibQuS information system architecture. Technologically, we decided to rely on standards like Internet as network communication protocol and SQL-databases as system interfaces, because this setting describes the typical industrial situation quite well. Because we wanted to leave the methods as autonomous as possible and also keep there information management effort small, we decided to install a communication organization system, the so-called *Quality Trader* that, alike the trader concept used in open distributed processing in wide area communication networks, stores and provides knowledge about the whole information system: It contains the MQM (repository level 2), and all schema information of the SQL-databases that together form level 3 of the repository with respect to the concept `Object` and consists of two parts :

1. The *Product and Process Model* (PPM) which is a global schema where information is stored that requires overall agreement because it is used in (almost) every method, e.g., product structure trees, or manufacturing process information.
2. *Private exchange schemas*, describing information of interest only for few agents like specific method results, e.g., matrix structures of QFD.

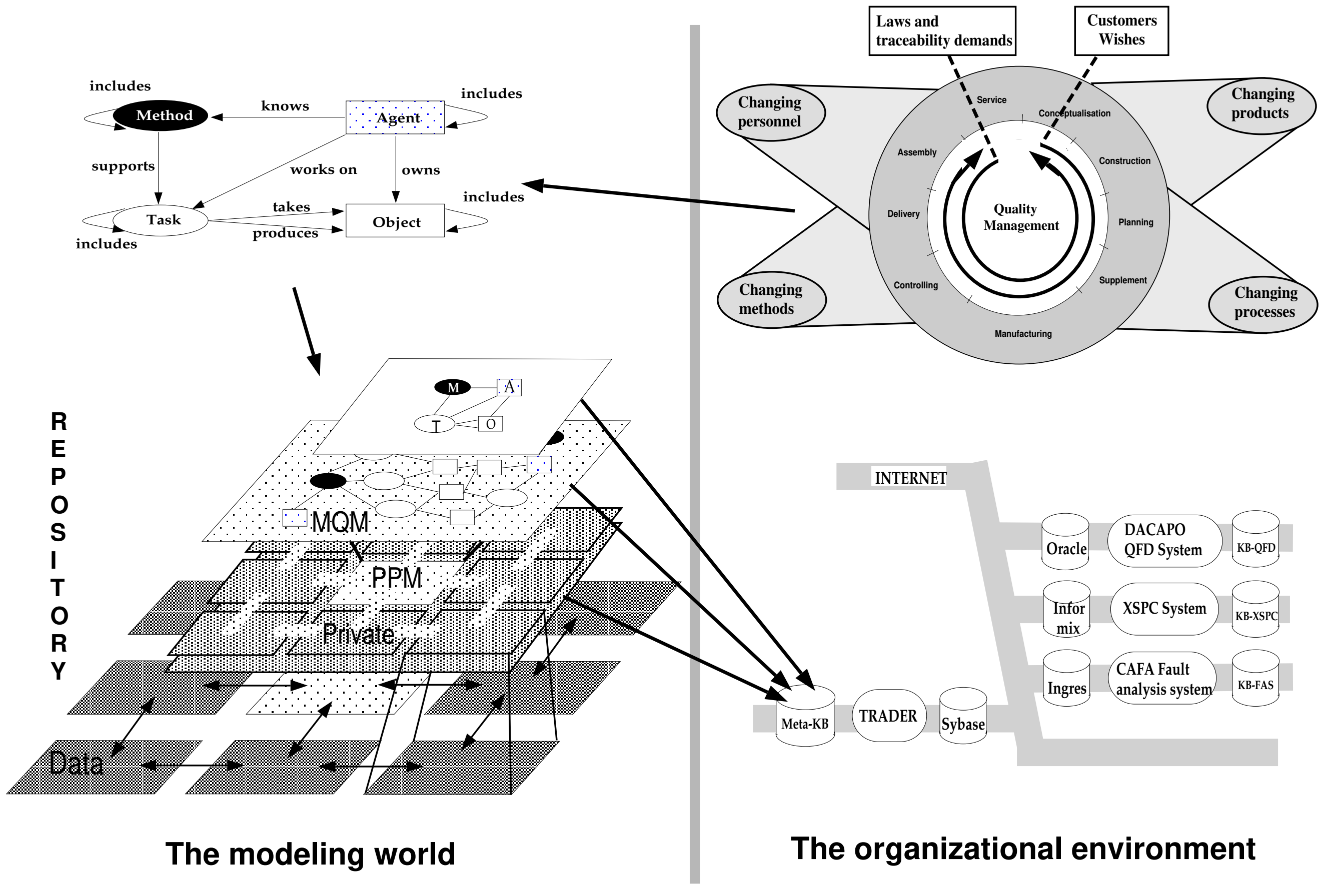

Figure 1 The WibQuS project

The distinction between those schema types prevents the company data schema from getting unmanageable and again highlights the autonomy of the participating groups: As long as information provided by a group is only of limited interest for one or two methods in the system, the group remains responsible for the schema, its evolution, or bilateral negotiations about information needed by other methods (c.f. sect. 3,4). Only information of global interest should be represented in a globally identifiable, accessible and task suitable way.

Nevertheless, all schemas, private or global, in WibQuS have to be represented in the Quality Trader, because it is responsible for the execution of all communication based on the SQL-interfaces, especially if they refer to data distributed over several systems. This communication handling is facilitated in two ways: First all system configurations and

Internet addresses are represented at level 3 of the repository, instantiating the described `Methods`. So all routing informations are part of the Trader's knowledge base. Second, the SYBASE OmniSQL[4] server is able to connect to and communicate with all databases included in the system architecture, what simplifies the query adaptation and data transfer between the four used database brands. This architecture forms a basis for several communication and information management tools described in the next section.

3 Conceptual Models at Work

We showed that conceptual modeling of tasks and methods in combination with a repository architecture supports a business process oriented integration approach that ends up in an distributed information system of relatively autonomous functional islands coupled by information flows. We will now describe the way, information management and processing tasks can be facilitated by the given architecture and special tools built upon it.

During the WibQuS-Project we identified three main tasks which our customers, the quality management engineers wanted to be supported:

1. Fast access to frequently used information.
2. Search mechanisms to find, browse and access information and its providers in the distributed environment.
3. Adding and deleting information flows to the given system structure.

Automating Information Access

As mentioned before, all communication between methods included into the system is based on SQL-statements communicated via the Quality Trader (QT) because of the technical limitations in the project but also because from the information management

[4] SYBASE OmniSQL is a trademark of Sybase Inc.

viewpoint there's a need to keep track of information flow in the distributed system (see sect. 4). The basic process of information request handling consists of the following steps:

1. Send request to QT
2. QT finds information source(s) using level 3 of the repository.
3. SYBASE Omni-SQL transfers the query into the database dialect(s) of the source(s)
4. Execution of the (distributed) query.
5. QT collects the answer(s) and transforms it into the dialect of the requesting system.
6. QT sends answer table to requesting system.
7. QT documents the querying process for statistical purposes.

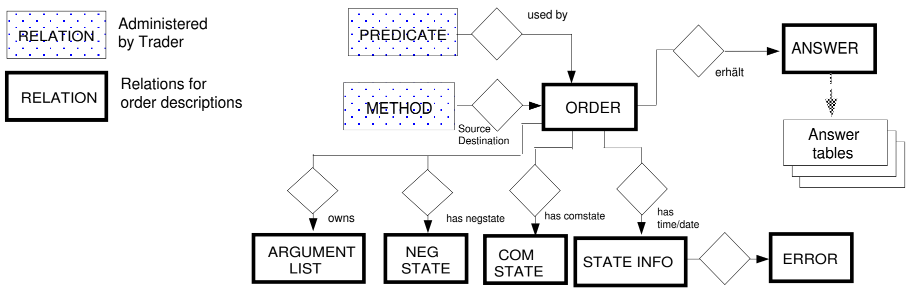

Figure 2 The Communication Exchange Relation

To keep the information request technique as simple as possible for standard requests and to support more communication than pure database queries, we designed a global communication schema named *communication exchange relation* ([26], c.f. figure 2). This schema allows to take a relatively simple predicative view on information requests, where the user just names a **predicate**, fills in the **argument list** and puts it into his order request list what sets the **comstate** of the **order** to 'one'. Now the above information handling process is performed by using triggers related to **comstate** with two additional steps:

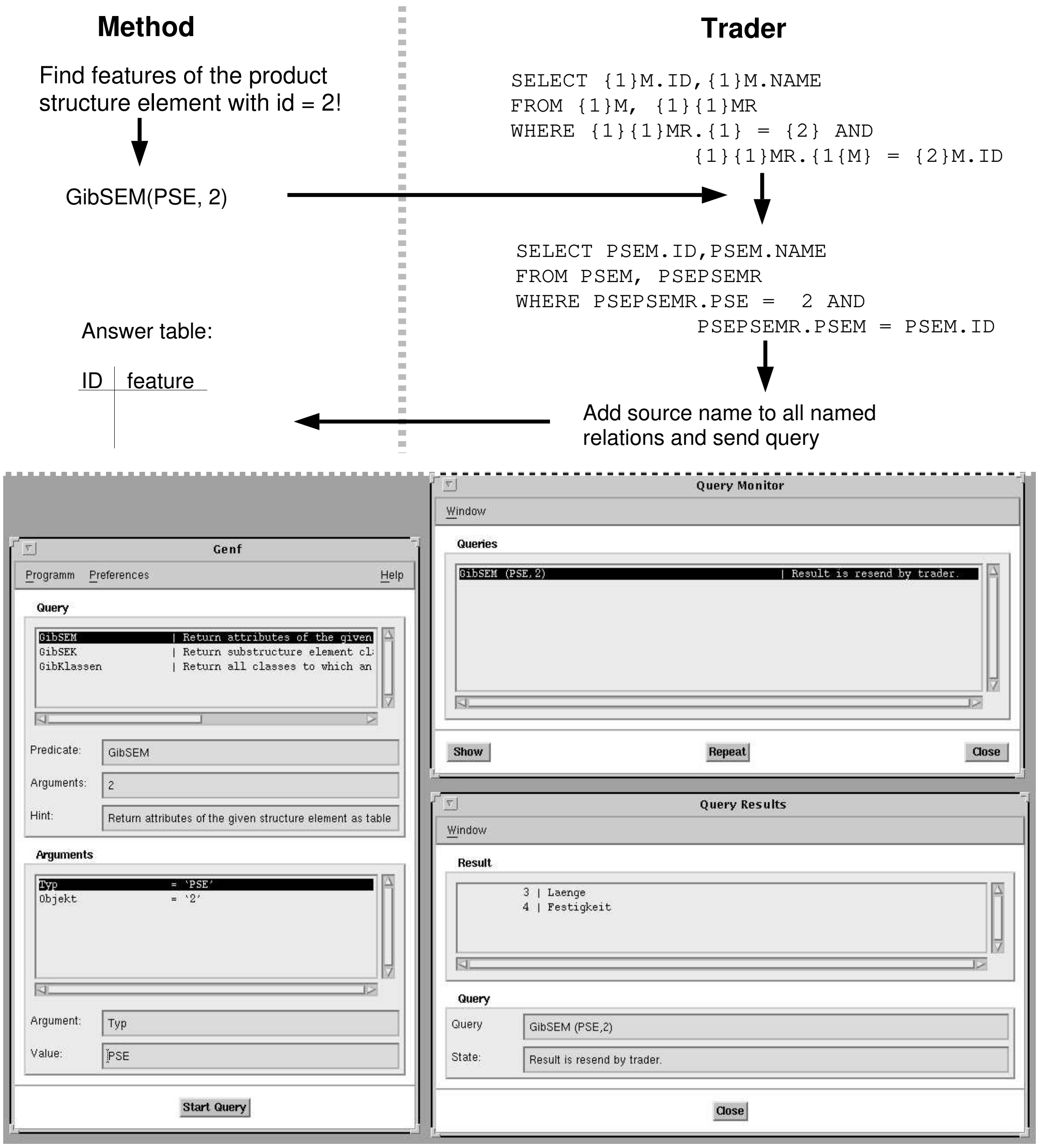

Figure 3 Requesting product element features by variable queries

2a QT looks up the query represented by the **predicate**.

2b QT instantiates query variables with the **argument list** (see figure 3).

Depending on the type of predicate referred to in the request, the **order** can be a query as in the example of figure 3, a message or a real assignment what would lead to a negotiation process between the involved methods supported by a mechanism based on

negstate. Therefore, the predicates are the level 3 instances of the `Task` concept in the repository, because they describe those parts of the task the information system deals with.

After being defined and included into the QT, the predicates can be used in two manners: First, the information request can be hard-coded into a method support system, if the information is highly standardized and the method execution process is well understood. Second, the request can be formulated and sent by the executing agents using the GENF tool displayed in figure 3. In this form based tool the query example is selected from a list of predicates and the arguments are filled in using the GENF argument window. The execution can be monitored by the Trader as well as by the requesting system using the query monitor and all answers are displayed in the result window.

Searching for Information

The idea of predefined, variable queries proved its relevance in the WibQuS-Environment only for a limited set of information flows. Quality engineers were not able to formulate their information needs as queries in advance unless the information was highly standardized, e.g., product structure trees or attributes of process steps. Furthermore, they agreed that information needs especially in the design process often arise unpredictable and therefore search mechanisms to explore the distributed environment were considered very helpful.

Again, the conceptual models of method interaction and product-/process structures were the starting point for a browsing and querying tool currently under development (c.f. figure 4)[5]. Starting from the browsing facilities of ConceptBase and recent approaches in graphical query languages ([7], [29]), we are currently creating a *task and view-oriented information system browser*, where the engineer begins his search with a representation

[5] A more detailed description of the tool is given in [19].

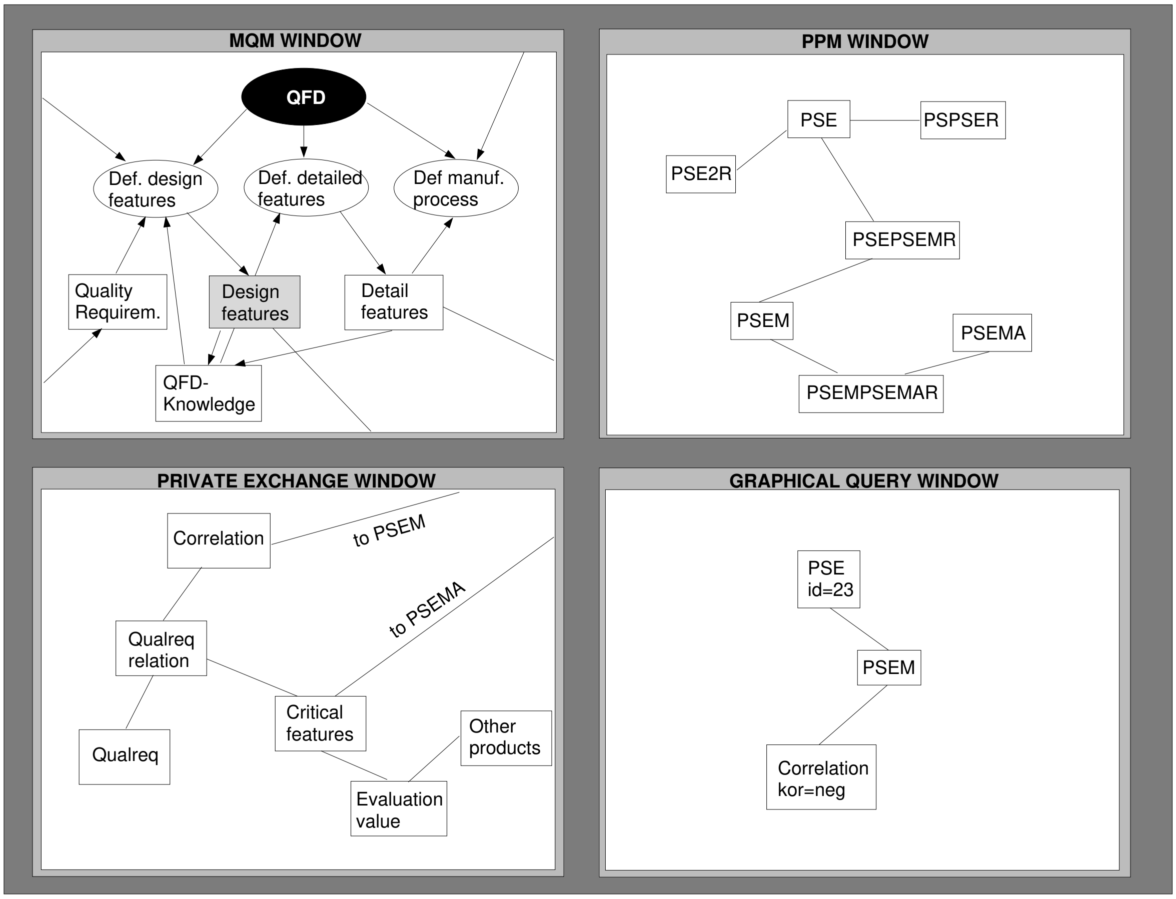

Figure 4 The information search and access tool

of the method he works on at a MQM-window (here: QFD) and two schema windows representing the PPM and private exchange relations.

The engineer now can move two ways: First, he can look for informations provided to his task by other methods clicking on the task-widget in the MQM-window. This shows the inflow of information objects as modelled in the MQM. By selecting information objects (here: design features) the windows for the schema representation change to the relations representing these information objects. Second, he can select an element of the PPM and the MQM-window shows methods providing information related to that element. Now the engineer could proceed like in the first option, but only relations connected to the selected PPM-element are represented in the schema windows.

After finding the relations needed, the user can group and restrict relations in the graphical query window (here: negative correlations between features of the product part with id = 23) and an SQL-query is generated and processed automatically using the knowledge from the MQM and the SYBASE OmniSQL-gateway in the way described in the previous section

This tool complements the predefined queries, because it allows user-friendly, graphic based search and access to information which is not used frequently. This *view oriented and task related access* to the information structures of the distributed environment avoids the phenomenon of getting lost in information space and therefore adds to the acceptability and efficiency of the information system. Additionally, the graphical query mechanism can be used to model new predefined queries if information requirements or information support level change.

Defining New Information Flows

The information system as it is implemented yet only reflects information flows as they exist at the moment. But as mentioned in the introduction, information needs change with technological or methodical evolution and with external demands. Slowly but surely these changes will lead to new, emerging information flows that have to be included into the information system.

As the described tools support both communication and information representation in the distributed information system, they can be used to support the inclusion of new information flows into the system. The first step is the announcement of the availability of or the need for new information in the whole system. In addition to frequent information management team meetings this can be done by sending messages using the GENF tool. Therefore we installed two special predicates called request announcement and availability announcement. This messages will be send to every method in the system and its arguments describe the relational context of this request by referring to relational schemas where new information is stored or additional information is needed. A comment gives further specifications about the needed/provided information.

If a needed information is already available one can go directly to step 3, the installation of a new information flow. Otherwise there has to be a step 2, where the request should be discussed in a team meeting. Depending on how vital the information is for method performance and how costly it would be to acquire the information inside or outside the company, a decision can be made. But this step is definitely not in the scope of support by the information system.

In step 3 the installation of a new information flow is simplified because the browsing and access tool is a front-end to the repository and even more, together with the SYBASE OmniSQL-Gateway, to the whole system. If the graphical query window is functionally enhanced, it can act as a system design window, where tell/untell operations on the ConceptBase repository and create/update/delete operations on the relational databases can be performed. This allows an engineering process where in a first step that an `Object` would be added to the MQM model and connected to producing and consuming tasks. In a next step the relations of the private exchange schema or the PPM have to be adjusted and new relations must be connected to the information objects of the MQM. Finally, variable queries are probably formulated using the new graphical representation to provide fast information access if needed.

4 Information Flow Evolution — Some WibQuS experiences

When it came to designing the architecture of the WibQuS quality information system, at first there existed the notion that all methods should have two databases: a private one, where they could store data specially needed for their applications and a communication database where the information accessible for other systems should be stored according to a global schema, the PPM. Each information request should be performed automatically by the method supporting systems hard—coding the predicates described above. Both ideas turned out to be a little bit shortsighted with respect to information management aspects.

On one hand the PPM grew very fast. This caused some schema understanding problems. Only a limited amount of relations could be defined according to the European manufacturing data standardization approach STEP . A lot of other concepts like feature correlations, cause-effect-relations or feature values have been added to the model by those who came first and with the growth of the schema all others were forced to press there information into the given specifications or they tried to go round the definition problems by adding new relations. This way of working is the best precondition for monotonic growth of the schema, because each relation is always used by somebody. This makes global schema evolution extremely costly or even impossible after a short period of time.

On the other hand, it was obvious after the agent and task oriented development process, that information needs can be planned only to a limited extend and that there have to be mechanisms for ad hoc requests to the information system. But not only the 'when' was impossible to predict but also the 'what'. Therefore, the tool and schema development has been currently adapted to the information evolution process described in figure 5.

This process trivially implies a common support for the definition of information provided to a distributed information system. But regarding the WibQuS experiences this new defined information should stay under personal responsibility unless there is a need for globalization. This need is typically an external force like market requirements, laws or external standards like STEP which might trigger information engineering efforts

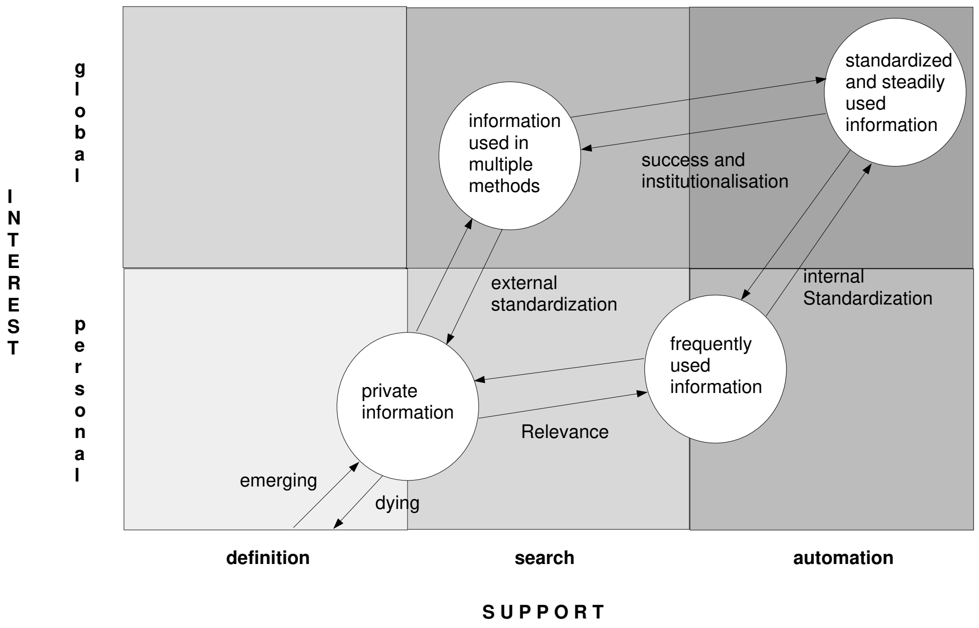

Figure 5 The evolution of information flows with respect to support and globalization

that skip the personal information stage and lead directly to a global schema. The stage of support depends on the success of the globalization and/or on the availability of cost effective tools. But often there are standards that were either not successful at first hand because they were not embedded in the existing business processes what caused low acceptance[6] or there is simply no acceptable support available yet (again: STEP).

The necessity of supporting private information communication arises with the frequency of this information being used by other methods. In the WibQuS context one could start with browsing the information system for the needed information until this becomes to time consuming and a higher degree of automation is required which can be implemented by variable queries. Implementing automated queries directly for every new information would lead to a proliferation of predicates and to falling acceptability of the GENF tool because searching for the right predicate might take longer than browsing the information system[7].

---

[6] Ask some German car manufacturer suppliers about being forced into ISO 9000 certification by their customers!

[7] A critical level has not been reached in the WibQuS project yet. It is obvious that the number of predicates will grow with n*m where n describes the number of methods and m describes the overall number of relations in the distributed information system.

The natural way for information to become part of the global schema is by internal standardization because of widely accepted relevance of the information based on successful experiences. It is proven that these success stories spread through the organizational grapevine for sure [9]and this might lead to more requests for successfully used information and to standardization in the end.

Nevertheless, there is still the problem of measuring who uses information and how often it is used in order to take the step from personal to global representation (or just as important the other way round) and to a higher (or lower) step of support. The critical level has to be defined by information management teams, but using the Trader architecture one could keep track of the overall 'hits' on information or how often a predicate is used at least in a technical way.

5 Future Directions

The WibQuS project showed that business process change management goes hand in hand with managing information flows. Furthermore, the project results validated the feasibility of our information management approach based on this idea and described in this paper. The modeling of quality management methods and their interactions proved to be a good starting point for process integration, information system design in the given environment, and task oriented information and change management along the described quality management processes.

The repository based integration of conceptual models of the processes and of the information flowing between the process steps builds the cornerstone of the Trader architecture, the technological solution to the presented management approach, which can be implemented relatively easy because it is based mainly on standard technology like SQL-databases or Internet. Built on those standards, conceptual models and Trader architecture constitute the technical and conceptual environment for several tools currently under development, supporting information management at various levels of automation and enabling fast adaptation to changing information needs.

Nevertheless, this support is restricted by the technological means integrated into the architecture, namely the SQL-based communication. One thing we've learned during WibQuS is that communication should be performed using various channels to optimize information flow. This includes a certain level of redundancy which is often needed as well as task oriented suitability of media (see also, e.g. [8]). Certainly, database technology will become more powerful with respect to multimedia, but the integration of multiple communication channels is a main challenge for task oriented information management.

Additionally, the results of the time-consuming repository building process has been exploited yet only to a limited extend. The process of information system planning based on the given models and the workload reported by the trader, which has been raised in the last section is analyzed at the moment. Furthermore there are efforts to use the described models as a starting point for workflow management along quality management processes.

Bibliography

[1] M. Abramovici and S. Bickelmann. Engineering Data Management Systems – Requirements, State of the Art, and Potentials (in German. *CIM*, (5):20–28, 1993.

[2] Y. Arens, C.Y. Chee, C.-N. Hsu, and C.A. Knoblock. Retrieving and Integrating Data from Multiple Information Sources. *Int. Jour. of Intelligent and Cooperative Information Systems*, 2(2):127–158, 1993.

[3] M.L. Brodie and S. Ceri. On Intelligent and Cooperative Information Systems: A workshop summary. *Int. Jour. on Intelligent and Cooperative Information Systems*, 1(2):249–290, 1992.

[4] E. Brynjolfsson and H. Mendelson. Information Systems and the Organization of Modern Enterprise. *Journal of Organizational Computing*, 3(3):245 – 256, 1993.

[5] D.A. Carlson and S. Ram. A Knowledge Representation for Modeling Organizational Productivity. *Journal of Organizational Computing*, 2(2):155 – 180, 1992.

[6] M. Chen, Y.I. Liou, and E.S. Weber. Developing Intelligent Organizations: A Context-Based Approach to Individual and Organizational Effectiveness. *Journal of Organizational Computing*, 2(2):181 – 202, 1992.

[7] M.P. Consens, I.F. Cruz, and A.O. Mendelzom. Visualizing Queries and Querying Visualizations. *ACM SIGMOD*, 16(3), 1992.

[8] R.L. Daft and R.H. Lengel. Organizational Information Requirements, Media Richness and Structural Design. *Management Science*, 32(5):554 – 571, 1986.

[9] D.K. Goldstein. Computer–Based Data and Organizational Learning: The Importance of Managers' Stories. *Journal of Organizational Computing*, 3(4):417 – 441, 1993.

[10] D. K. Hammer. Lean Information Management: The Integrating Power of Information. In H. J. Pels and J. C. Wortmann, editors, *Integration in Production Management Systems*, pages 147–163. Elsevier Science Publishers B.V., 1992.

[11] U. Harms. Generals and Car Manufacturers take Advantage of CALS (in german). *Computer Zeitung*, 26(3):21, 1995.

[12] G.P. Huber and R.R. McDaniel. The Decision-Making Paradigm of Organizational Design. *Management Science*, 32(5):572 – 589, 1986.

[13] M. Jarke, S. Eherer, R. Gallersdoerfer, M.A. Jeusfeld, and M. Staudt. ConceptBase – A Deductive Object Base Manager. *Journal of Intelligent Information Systems*, 3(3):1–37, 1994.

[14] M. Lynne Markus and D. Robey. Information Technology and Organizational Change: Causal Structure in Theory and Research. *Management Science*, 34(5):583 – 598, 1988.

[15] Jarke M., Jeusfeld M., and Szczurko P. Three Aspects of Intelligent Cooperation in the Quality Life Cycle. *Int. Jour. of Intelligent and Cooperative Information Systems*, 2(4):355–374, 1993.

[16] C. Menzel, R.J. Mayer, and L. K. Sanders. Representation, Information Flow, and Model Integration. In C. Petrie, editor, *Enterprise Integration Modeling*, pages 131 – 141, 1992.

[17] J. Mylopoulos, T. Rose, and C. Woo. Task-Oriented Development of Intelligent Information Systems. In M. Papazolou, editor, *Int. Conf. on Intelligent and Cooperative Information Systems*, pages 206 – 219, Rotterdam, The Netherlands, 1993.

[18] H. J. Pels and J. C. Wortmann. Integration in Production Management Systems: An Integrating Perspektive. In H. J. Pels and J. C. Wortmann, editors, *Integration in Production Management Systems*, pages 1–13. Elsevier Science Publishers B.V., 1992.

[19] P. Peters. A Task and View Oriented Graphical Interface to Federated Databases. In *submitted to Int. Conf. on Decision Support Systems*, Hong Kong, 1995.

[20] P. Peters and M.A. Jeusfeld. Structuring Information Flow in Quality Management. In *Int. Conf. on Data and Knowledge Systems for Manufacturing and Engineering*, pages 258 – 263, Hong Kong, 1994.

[21] P. Peters and P. Szczurko. Integrating Models of Quality Management by an Object-oriented Repository. In *2nd Biennal European Joint Conf. on Engineering Systems Design and Analysis*, London, England, 1994.

[22] T. Pfeifer. *Quality Management (in German)*. Carl Hanser Verlag, Muenchen, 1993.

[23] F. Roithmayr and J. Wendner. Results of an Empirical Study on Relations between Organization Strategy and Information System Strategy (in German. *Wirtschaftsinformatik*, 34(5):472 – 480, 1992.

[24] M.S. Scott Morton. The 1990s research program: Implications for Management and the Emerging Organization. *Decision Support Systems*, (12):251–256, 1994.

[25] E.-J. Sol. CIM – Communication and Information in Manufacturing. In H. J. Pels and J. C. Wortmann, editors, *Integration in Production Management Systems*, pages 13–21. Elsevier Science Publishers B.V., 1992.

[26] P. Szczurko. Integration of Distributed and Heterogenous Databases in a Federated Quality Management Architecture (in German). *submitted to GI Jahrestagung*, 1995.

[27] H.-J. Warnecke. *The Fractal Firm (in German)*. Springer-Verlag, 1992.

[28] C.C. Woo and F.H. Lochovsky. Knowledge Communication in Intelligent Information Systems. *Int. Journal of Intelligent and Cooperative Information Systems*, 1(1):203–228, 1992.

[29] J. Zhou. GUI to Databases – Survey and Practice. *GI Datenbank Rundbrief*, 13:49–51, 1994.