Implementation Approach of ERP with Mass Customization

Yu ZHAO, Yushun FAN

CIMS Engineering Research Center, Department of Automation, Tsinghua University, Beijing, China 100084

zhaoyu96@ tsinghua.org.cn, fan@cims.tsinghua.edu.cn

Abstract: This paper analyzes the shortage of traditional ERP systems in the current dynamic and competitive enterprises environment. The new generation ERP system needs to be frequently customized with low cost, high quality, and efficiency, as is similar to the product of Mass Customization (MC). Due to this kind of similarity, an implementation framework of ERP with MC principles (MC-ERP) is proposed based on the three fundamental principles of MC. An enterprise modeling-based enterprise total solution, which is the starting point of this framework, is introduced. In order to solve the function deployment approach, which is a key technology of the framework, an approach based on quality function deployment methodology is also discussed. For realization and validation, the architecture of a toolset for implementing MC-ERP is finally proposed, and the enterprise modeling tool, the kernel of this toolset, has been developed.

Key Words: ERP, mass customization, enterprise modeling, workflow, quality function deployment

1. Introduction

In this century changes in market requirements are increasingly rapid, and competition is increasingly keen. The traditional mass production, which reduces the production cost and shortens the production cycle, cannot keep up with the needs of a dynamic market; however, traditional customization, which aims at satisfying the market and individual customers’ requirements, cannot solve the problems of high cost and slow delivery time. Thus, a whole new production pattern of mass customization emerges, combining mass production with customization.

Mass customization (MC) is a production pattern integrating the enterprise, customer, supplier, environment, and most other enterprise resources to deliver customized products and services without losing the features of mass production, such as low cost, high quality, and high efficiency. MC reflects the concepts of system theory and global optimization and adopts various methods of standardization technology, modern design, information, advanced manufacturing, etc. The technology system of MC consists of four integrated parts: the basic principles of MC, development and design technologies for MC, management technologies for MC, and manufacturing technologies for MC (Qi, Gu and Tan 2003).

At the same time, with the development of information technology, enterprise resource planning (ERP) systems play an increasingly important role in the enterprise management domain. Particularly in China, implementation of ERP systems has become a de facto kernel task of enterprise informatization. Aiming at the common problems of ERP, such as low success rate, long cycle time, and high implementation cost, many researchers and ERP suppliers have come up with various solutions from different aspects. From the business management aspect, the ERP implementation solution is said to be based on business process reengineering with the combination of “push” and “pull” (Luo, Tan and Chen 2003). From a system development aspect, most ERP systems are now developed based on component and reconfiguration technologies. Bann has proposed the concept of Dynamic Enterprise Modeling (DEM), and SAP uses the technology of component tailoring based on the enterprise model. Both help improve the flexibility of systems.

The purpose of Intelligent Resource Planning (IRP) is to quickly adapt the system to the market with intelligent technologies. IRP is also being researched around the world, though for the currently severe competition situation there are still some shortcomings in traditional ERP systems: 1) Due to the highly dynamic customer requirements and product data of enterprises, ERP systems must be integrated closely with other enterprise information systems, particularly Product Data Management (PDM), Customer Relationship Management (CRM), and Supply Chain Management (SCM) system, though it is very hard for traditional ERP systems to meet these requirements. 2) As to the functionality of the ERP system, traditional ERP systems, which are developed from MRP, cannot analyze the restriction of enterprise resource and therefore are not able to face the resources’ high-share problem in the current environment. 3) The inner structure of traditional ERP systems is still rigid. Though most ERP system suppliers claim that their components are abundant and can be combined freely according to requirements, the systems can only be configured into finite pre-established business processes. Therefore, they are unfit for the dynamic ambiquity brought by customization and other changes required by the market. As a result, the cycle of implementation or adjustment of ERP systems is slower than the enterprise and market cycle of requirement changes.

At present, most researchers focus their work on development and design technologies for ERP, especially product modeling technologies; however, aiming at the gaps between the traditional ERP systems with the requirements of new-generation ERP systems analyzed above, the solutions in the area of management technologies are seldom discussed. At the same time, we can observe that the new requirements of ERP systems are similar to the features of MC that satisfy both rapid implementation and flexible customization. Since MC has plenty of successful practical experiences, we consider that the principles of MC should also be applicable to the implementation of ERP systems. The purpose of this paper is to propose an ERP implementation approach based on the fundamental principles of MC and the research results of the project “R&D of new generation ERP system” funded by the Chinese National High-Tech R&D Program.

The rest of this paper is organized as follows. An implementation framework of ERP with MC principles (MC-ERP) is first proposed in Section 2. In Section 3 an enterprise modeling-based enterprise total solution, the basis of this framework, is introduced. In Section 4 the research results upon the key technologies of the framework of function deployment are presented. Toolset architecture to support the framework and some developed tools are presented in Section 5. Section 6 includes the summary and future work.

2. Implementation framework of MC-ERP

There are three basic principles in MC (Qi, Gu, and Tan 2003). 1) Principle of similarity: The kernel of MC is to identify and make use of the similarity among various products and processes, to identify and discover as much similarity of geometry, structure, function, and process among the products and processes as possible, and to make use of standardization, modularization, and serialization to reduce the diversity of products in order to increase the reusability of parts, components, and production processes. 2) Principle of reuse: Many units can be reused and recombined. Thus, this principle means making use of standardization, modularization, and serialization by products or processes recombining to completely or partly transform the problem of customization production into the problem of mass production for low cost, high quality, and high efficiency. 3) Principle of globalization: MC is a kind of system engineering, so the researchers need to integrate all kinds of knowledge and domains and analyze and tackle the MC problems holistically.

The three basic principles above direct the research and application of all the technologies for MC. On the other hand, the ERP system can also be regarded as a kind of industry product. In order to customize the ERP system with low cost, high quality, and high efficiency, we can also apply the concepts of MC to the development and implementation of ERP systems. We also call this the mass customization of ERP (MC-ERP).

Thus, we propose an implementation framework of MC-ERP based on the three basic principles shown in Figure 1, integrated with enterprise modeling technology, workflow technology, component technology, integrated platform technology, and knowledge management technology.

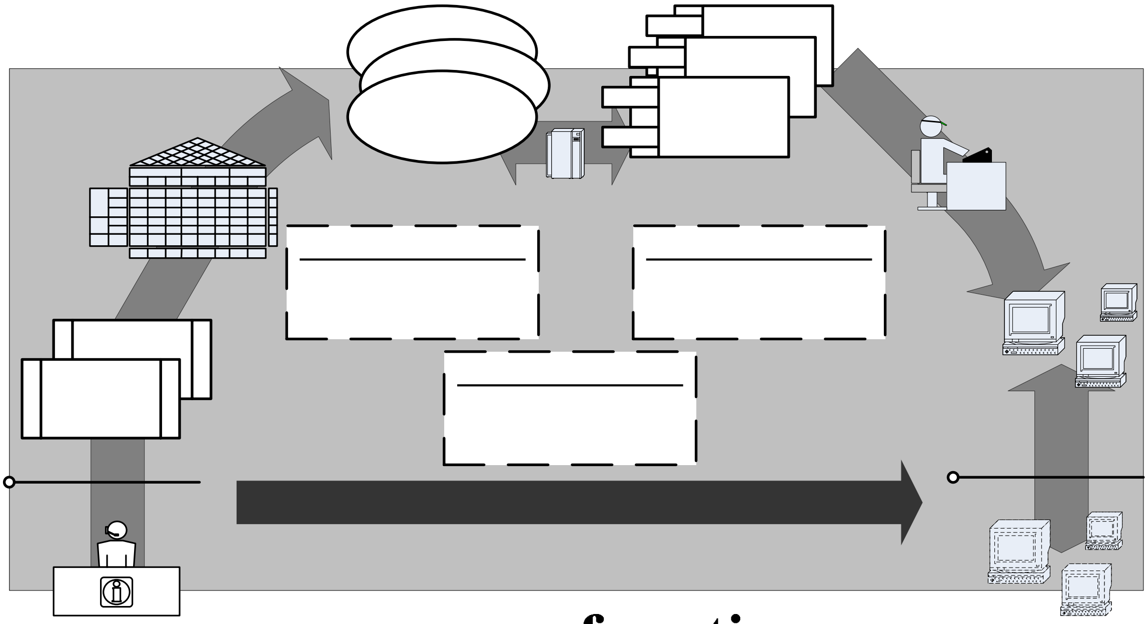

Figure 1. Implementation framework of MC-ERP

2.1 Enterprise total solution

According to the basic principle of globalization, the implementation of the ERP system is not just about developing and running one information system. The implementation approach should holistically consider the business strategy, management pattern, product structure, and business process of enterprise and should guarantee consistency between the system and the enterprise. On the other hand, the implementation involves more than a single ERP system. The approach should take into account the other systems that exist now or that will be developed in the future, and it should also guarantee consistency with them from both business and data aspects. Thus, the basis of this framework is the enterprise total solution.

2.2 Customization – Knowledge platform – Enterprise products and processes

The meaning of MC-ERP customization is two-fold: 1) In the implementation process for a given enterprise, the reference business pattern given by the ERP supplier should be customized according to the reality of this enterprise. 2) When the products of the enterprise are customized by the customer, the ERP system should be customized to match the design, production, and management of new products.

To understand the customization requirements and convert them into the modification of enterprise products and processes, which are represented by a standard code or model, we must rely on the support of the knowledge platform and knowledge management system because what is behind the customization ability and realization is the knowledge and ability of cognition and innovation (Xia 2002).

2.3 Enterprise processes – Function deployment – Enterprise functions

The business processes and activities are numerous and complicated, but according to the MC basic principle of similarity, we can extract the similarity of process and function from these business processes. The similarity of process indicates that some business processes appear repeatedly during the enterprise operations. These business processes have similar activities and a logical structure. For example, the storage process for a shaft or gear is the same, including checking, completing the storage form, assigning the lot, and putting the item into storage; therefore, the storage process for parts can be standardized. The similarity of function indicates that, though some processes vary with activity flow, their functions are the same. For example, the storage process of a non-ferrous metal part has additional activities, including surface treatment and setting the alarm for periodic check. Although the storage process of a non-ferrous metal part and the process of a regular part have different activity flows, they both realize the part storage function. Thus, according to the principle of functional similarity, this storage function unit can be modularized, and there are many switch processes with different entry parameters. Because the systems are composed of functional modules and enterprise processes show the business requirements of these modules, these functions should be extracted from the business processes. We call this task function deployment.

2.4 Enterprise functions – Binding and mapping – ERP components

Along with the development of the software reuse idea, software engineering has entered the era of component engineering. Today most ERP systems are made up of components, and large ERP suppliers such as SAP and BANN all have their own enormous component libraries in order to configure ERP rapidly for variant enterprises. The components of ERP are usually developed according to the enterprise functions. Therefore, the binding and mapping between enterprise functions and ERP components should be done after the function deployment. With the relationship of binding and mapping, the adjustment of ERP component architecture can be synchronized consistently with the adjustment of the business processes consistently.

2.5 ERP components – Workflow platform – ERP system

Although most ERP systems are developed using component technology, the architectures mainly focus on the information processing and information integration (Li and Fan 2003). Business logics realized by the components in a series can be adjusted with limited flexibility, but all the potential business logics are solidified in the program codes of the components; that is, every component knows which components might be invoked after itself. Thus, in the dynamic environment the program code and interface of such traditional ERP components would be frequently modified. A workflow management system is a kind of system that executes the business processes automatically, centering on the process to realize the system integration. Therefore, to increase the flexibility of the ERP system, we should separate logic from function in the ERP component, let the workflow management system accomplish the business logic and transfer, and be a plug-and-play platform for ERP components. Moreover, using workflow as a platform complies with an important idea of MC – to move the customer order de-coupling point as far downstream in the production process as possible, using workflow to move the customization point of business logic from the upstream component development phase to the downstream component combination phase.

2.6 ERP system – Integrated platform – Other systems

As discussed above, an important requirement for MC-ERP is the ability to integrate with other information systems, especially PDM, CRM, and SCM. The support of integrated platform technologies is necessary.

3. Enterprise total solution based on enterprise modeling

From the global view of enterprise, the enterprise systems serve the whole enterprise business. Thereby, the implementation of an information system should follow the identification of business. We divide the implementation process of enterprise total solution into four major phases: business planning or modification, system planning or modification, system implementation, and system running or maintenance. In order to guarantee the consistency between the systems and the business, a public platform for these four phases is needed.

The enterprise model can realize the systematic and structural description of enterprise information and business information. During the implementation process of information systems, the enterprise model can be regarded as the common data for all the participants, including the enterprise decision maker, IT engineering, and system supplier. Moreover, under an integrated modeling framework, the enterprise model can be represented by various formats according to the phase of the implementation cycle of systems (Zhao and Fan 2004b). For example, business to be analyzed should be modeled by mathematical formal language, while in order to execute the same business automatically, it should be modeled by computer language. Thus, we can use the enterprise model as a common platform to support the four phases of enterprise total solution and link the system with business consistently.

An approach of enterprise total solution based on the enterprise modeling under the EMITS modeling framework (Zhao and Fan 2004a) is shown in Figure 2.

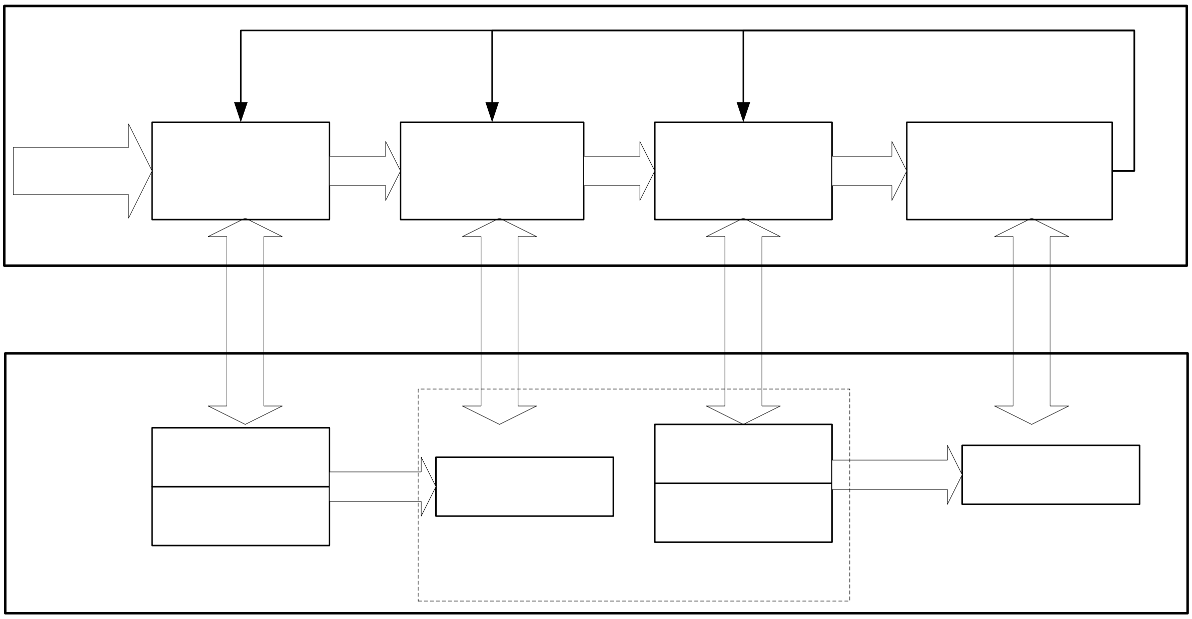

Figure 2. Enterprise total solution based on the enterprise modeling

3.1 Business planning/adjusting phase

During this phase an enterprise model should be set up at the requirement level, orienting entire lifecycles of products. The model of this level should keep the description of business processes as the kernel and integrate the product structure, organization structure, and resource structure. The goal of this model is to analyze the as-is business and adjust or optimize it according to the business goal and the requirements of customization. There are many analysis approaches with the enterprise model, such as benchmarking with reference models, simulation, and mathematics analysis methods. In the mass customization environment, the analytical results can be used to validate the product family model, which is extracted from the product similarity based on the guidelines of time, cost, use of resources, and so on. Then the decision maker can improve the enterprise by adjusting the resource deployment and organization structure according to the necessary product family structure or by adjusting the product structure according to the enterprise capacity. Therefore, this phase can guarantee that the information system design, which is based on the business model, is correct from the view of business. The business planning/adjusting phase completes the period from customization to enterprise products and processes of Figure 1.

3.2 System planning/adjusting phase

The task of this phase is to transform the business architecture into the system architecture. The system architecture includes the function structure, information structure, and integration framework of all the enterprise systems, not just the ERP system, and implementation strategy, approach, and schedule of systems. In the domain of enterprise model, enterprise functions and function structure are extracted from business processes in this phase, completing the function deployment of Figure 1. At the same time, data structure and relationships required by the information systems can also be collected from the input/output information of the business processes and activities. According to the analytical results of the previous phase, the decision maker can decide which functions need to be implemented by information systems according to cost, importance, and so on. If one function unit is selected for implementation, during this phase we also need to decide whether the system component for this function unit is to be outsourced, customized, or developed. This decision can be supported and assisted by the knowledge management system and the decision support system.

3.3 System implementation phase

During this phase information systems are built up based on the system architecture, implementation approach, and schedule, which are the outputs from the previous phase. Implementation includes three aspects: customization of the existing components, which sets the parameters and adjusts inner logic if necessary; development of new components, which satisfies new requirements from the business; tailoring and combination of components, which binds and maps these components to the corresponding function units, thus completing the binding and mapping process of Figure 1.

3.4 System running/maintenance phase

An information system based on the workflow platform can run and manage itself by combining its components automatically, and the workflow management system can also set up an effective system log and running data warehouse by itself. The log data can be analyzed with data mining technology in order to evaluate the running performance of the system and detect system errors.

4. Function deployment with enterprise process model

In this section we discuss the approach of function deployment in the implementation framework of MC-ERP. We divide the function deployment into two parts: deploying the function units and extracting the operational properties of function units and the relationships among them.

Deploying the function units is a process of applying the similarity principle – MC's first fundamental principle – to mine the functional similarity from the business processes described in the enterprise model. We choose House of Quality (HoQ) of Quality Function Deployment (QFD) as the tool to realize the deployment.

QFD (Govers 1996) is a planning process of the market-oriented product design and development, and it is the kernel technique of product quality engineering. The basic thought of QFD is that all the activities of the product development process are driven by the customers' requirements, preferences, and expectations. QFD assures that the product satisfies the customers by deploying the requirements, preferences, and expectations into the products and processes through "what" and "how." The primary method of QFD is to build HoQ, the relation matrix between the requirement elements and the designing elements: that is, to deploy the requirements represented by the customer language into the design elements represented by the technology language. With this basic idea, the QFD method has been widely applied in many fields besides the product innovation, and recently it has proved to be efficient in assuring the software quality in the software engineering field by practical applications (Elboushi and Sherif 1997).

Toward the ERP implementation, the business processes described in the enterprise model are the requirements from the enterprise—the customer of ERP, in fact. On the other hand, because the function units can be mapped into software components using the component-based design style of the information system, functions can also be regarded as the design elements for information engineering. Thus, the relation matrix between the business processes and the business functions can be built similarly using the HoQ tool of QFD. Because of the different research objects, the business engineering and the software engineering use and understand the different models. This relation matrix can also be used as the communication diagram between the business engineerings and the software engineerings.

Figure 3 shows a business-function relation matrix built by HoQ.

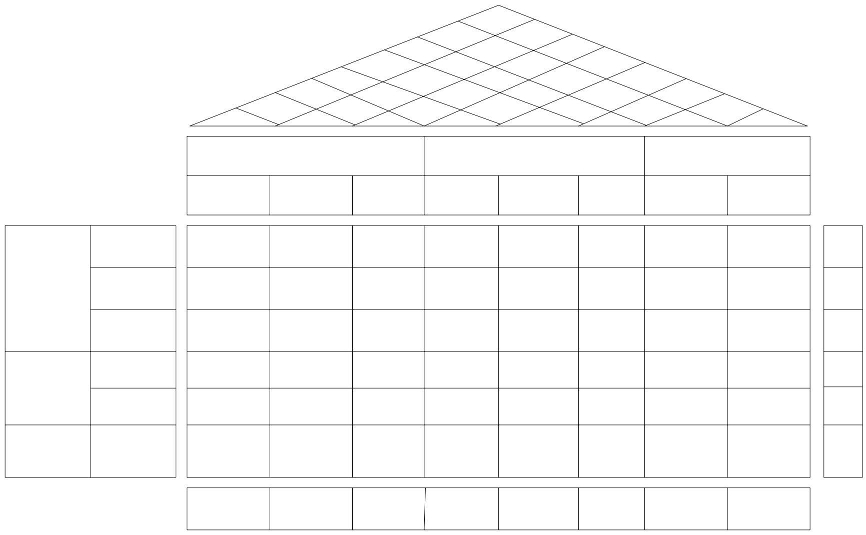

Figure 3. The process-function relation matrix

In this relation matrix the rows are filled with all the business processes described in the enterprise model, regarded as the business requirements of the ERP system, and the columns are filled with the function structure, regarded as the technology requirements of the ERP system. Usually, a software provider, which follows the component-based information system architecture, has an abundant software component depository for customers to choose components from. We can classify all the components in the depository by the function and put them into the column headers of the relation matrix. In addition, based on the result of the foregoing diagnosis and analysis of the enterprise model, the priority and importance of each process can be obtained according to the degree of bottleneck effect and relationship to the enterprise competition in the active business. Next, quantitive priority values are placed at the right side of the relation matrix. Similarly, the software characteristics of each component, such as cost, upgrade capacity, and efficiency provided by the software providers, are placed at the bottom of the relation matrix in order to provide the reference for the decision of the final ERP's function structure. Above the matrix another matrix is used to describe the dependency and interaction relationship between the components themselves, and the varying degree of tightness should be represented by different symbols. The grids, the core part of the matrix, are filled with the symbols representing whether the functional components of the column can accomplish the business process of the row.

After deciding the function units and function structure, operational properties of function units and the relationships among them should be extracted from the business processes in order to configure the ERP components. From the final process-function matrix we can get the functional property of each business process and activity. Then we can extract the information following the rules shown by Figure 4.

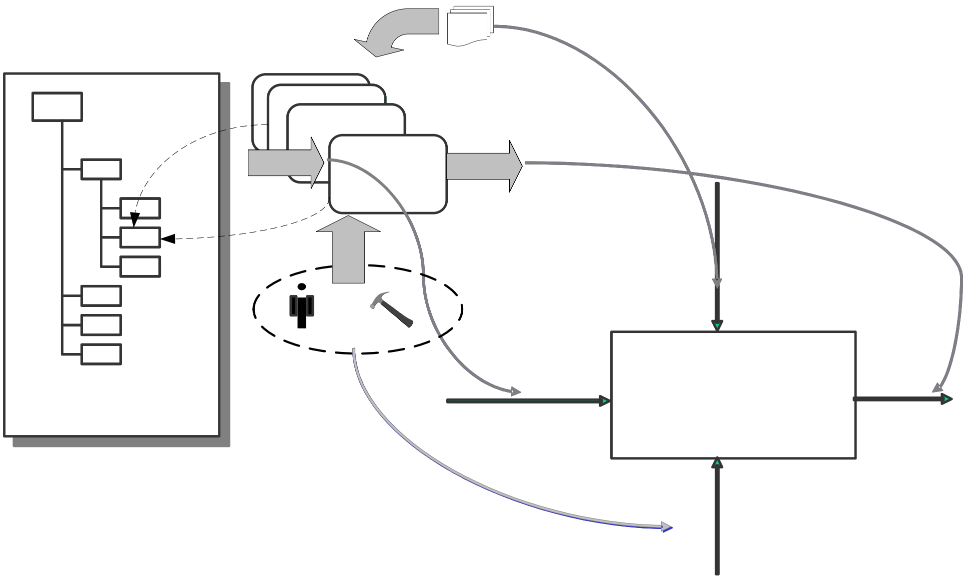

Figure 4. Extracting function model from process model

A business activity is given by a 5-tuple *<I, O, Or, R, D>*. *I* represents the input information or products of activity, *O* represents the output information or products, *Or* represents the organization units who are responsible for the activity, *R* represents the resources with which the activity is executed, and *D* represents the documents the activity uses.

A function unit is given by a 4-tuple *<FI, FO, FC, FM>* according to IDEF0. *FI* represents the input of the function unit, *FO* represents the output, *FC* represents the control, and *FM* represents the mechanism.

A is the set of all the activities. *F* is the set of all the function units. $AF \subseteq A \times F$ is the relation between activities and function units. $\forall f \in F$, define $A^f = \{a \mid a \in A, (a, f) \in AF\}$. Then,

$$f.FI = \bigcup_{a \in A^f} \{a.I\} \qquad f.FO = \bigcup_{a \in A^f} \{a.O\} \qquad f.FC = \bigcup_{a \in A^f} \{a.D\} \qquad f.FM = \bigcup_{a \in A^f} \{a.Or, a.R\}$$

5. Toolset for implementing MC-ERP

According to the implementation framework of MC-ERP, a series of tools needed to be prepared for this framework. The architecture of the toolset is shown in Figure 5.

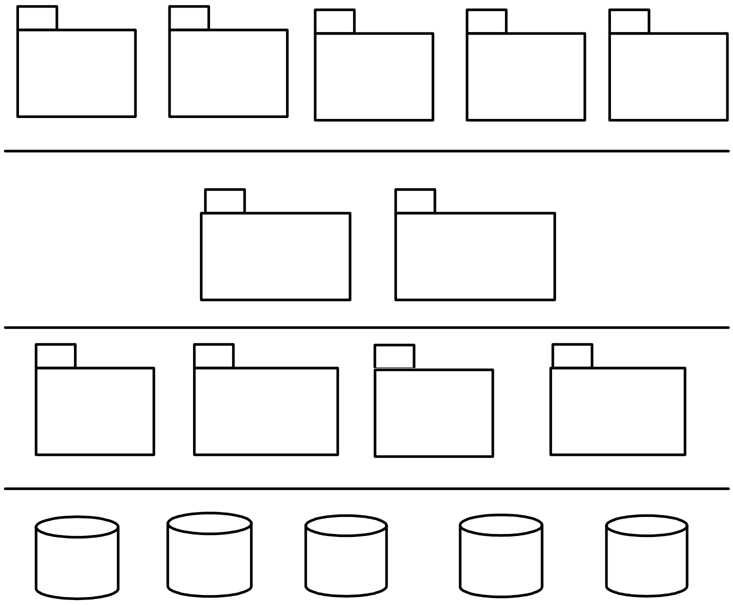

Figure 5. Toolset for implementing MC-ERP

Tools are divided into four levels:

1. Application Level

The tools at the application level are directly applied in the implementation process of MC-ERP. The planning package is responsible for collecting and evaluating the requirements from the enterprise or the enterprise's customers. The modeling and diagnosis package is responsible for creating the business model and complete the simulation and diagnosis with the model. Because enterprise modeling is the basis of the framework, this package is the kernel of the whole toolset. The screenshot of the enterprise modeling tool we developed is shown in Figure 6. The CASE package is responsible for supporting the development of new ERP components based on the enterprise model. The workflow management package is responsible for executing the ERP system and navigating the ERP components. The running analysis package is responsible for analyzing the log data from the running workflow.

2. Assistant Application Level

The tools at the assistant application level are used for assisting the tools at the application level, and they include two packages. The project management package is responsible for managing and controlling the process of implementing MC-ERP and managing the change of customization. The knowledge management package is responsible for knowledge discovery and collecting, for other tools, and for supporting the decision maker in making the decision.

3. Platform Level

The tools at the platform level serve the other tools at the two higher levels, providing them with access to the data level. The model manipulation package is responsible for model data query and manipulation for other tools. The model transformation package is responsible for the support of general model transformation theory and for achieving correct model transformation. The workflow engine realizes the running of the workflow management system, which is responsible for accessing the business instance data and log data. The visualization package is responsible for defining visualization rules and realizing the visualization of data.

4. Data Level

There are several databases at this level for storing all the application data for the toolset, including the model base and document base for business, component base for system configuration, and business instance base and log database for system running.

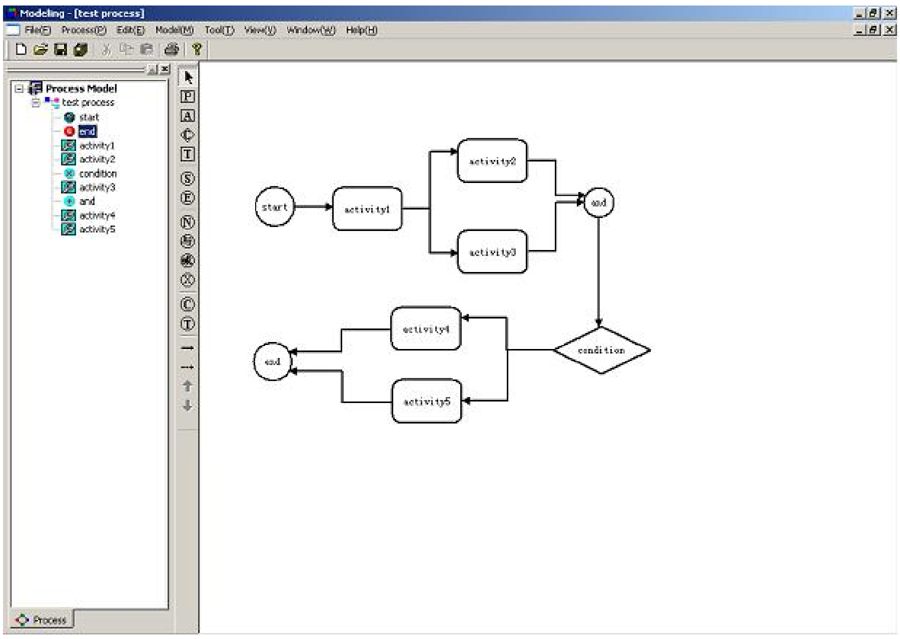

Figure 6. Screenshot of enterprise modeling tool

6. Summary and future work

In order to fill the gap between the traditional ERP system and the requirements from current dynamic environments, an implementation framework of new generation ERP is presented here. The framework is proposed based on the three basic principles of MC. These principles direct the research and application of all the technologies for MC. On the other hand, the ERP system can also be regarded as a kind of industry product. In order to customize the ERP system with low cost, high quality, and high efficiency, we can also apply the ideas of MC into the development and implementation of ERP systems. This framework can also be called the implementation framework of ERP with MC principles (MC-ERP). Based on this framework, its foundation (the enterprise modeling-based enterprise total solution) and one key technology (function deployment) are particularly discussed. In order to discuss the realization of this framework, the architecture of the toolset for implementing MC-ERP is also proposed, and the kernel package, the enterprise modeling tool, has been developed for validating the framework.

This research is still ongoing. With this framework and toolset architecture, the next step of work is to research the other key technologies in the framework, including the interaction between ERP components and business processes, ERP components interface standards on the workflow platform, the component family modeling, and so on. The other packages inside the toolset will be developed to validate and revise the framework.

Acknowledgements

This work was supported by the National High-Tech. R&D Program for CIMS, China (Grant No. 2003AA413210 and Grant No. 2003AA4Z2020).

References

Elboushi, M.I. and Sherif, J.S., 1997, Object-Oriented software design utilizing quality function deployment. *Journal of Systems Software*, 1997(38), 133-143.

Fan, Y-S. 2001, *Fundamentals of Workflow Management Technology* (Beijing: TUP, Springer). (in Chinese)

Fan, Y-S. 2004, The connotation and implementation roadmap for enterprise information system total solution, *Computer Integrated Manufacturing Systems*, 10(5), 481-486

Govers, C.P.M. 1996, What and how about quality function deployment (QFD). *International Journal of Production Economics*, 1996(46-47), 575-585.

Gulla, J. A. and Brasethvik, T., 2002, A model-driven ERP environment with search facilities. *Data & Knowledge Engineering*, 42(3), 327-341.

Stephen Haag, M.K. Raja and L.L. Schkade, Communications of the ACM, 39(1) (1996) p.41-49

Huang, S-X. and Fan, Y-S., 2004, Development and deployment of ERP system based on workflow technology. *Computer Integrated Manufacturing Systems*, 10(2), 139-143. (in Chinese)

Li, W-P. and Fan, Y-S., 2003, The application of workflow management technology in the ERP systems, *High*

Technology Letters, accepted. (in Chinese)

Luo, X-X., Tan, L-J. and Chen, W-M., 2003, The development of ERP under the environment of mass customization. *Information Technology*, 27(2), 86-88. (in Chinese)

Qi, G-N., Gu, X-J., and Tan, J-R., 2003, *The Technology and its Application for Mass Customization* (Beijing: China Machine Press). (in Chinese)

Xia, J-H. 2002, How about knowledge in the era of mass customization, http://www.amteams.org

Zhao, Y. and Fan, Y-S., 2003, Enterprise information engineering utilizing enterprise modeling with quality function deployment. *Proceeding of the 3rd International Conference on Electronic Commerce Engineering*, Hangzhou, China, 24-27 October (Beijing: World Publish Corp.), pp. 977-980.

Zhao, Y. and Fan, Y-S., 2004a, Integrated enterprise modeling framework for the informatization total solution. Control and Decision, 19(7), 769-772. (in Chinese)

Zhao, Y., and Fan, Y-S., 2004b, Research on enterprise modeling based implementation method for the total solution of informatization. *Aeronautical Manufacturing Technology*, 2004(8), 53-56. (in Chinese)