

An Enterprise-wide Process Centric Framework for Manufacturing Information Technologies

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Abstract – Industries have moved from contract manufacturing to providing higher value-added knowledge-based services like product design & development. As a result, capabilities for Enterprise-wide Collaboration, Product Lifecycle Management, Process Workflow Management, and Manufacturing Planning & Scheduling have become critical especially among the Small and Medium size Enterprises (SMEs). This paper describes an R & D project at SIMTech that developed an Enterprise-wide Process-Centric Information Technology (EPC-IT) framework to address such industry needs, and how it helped companies to plan, manage and control their business operations efficiently.

Keywords: Enterprise-wide collaboration, Product lifecycle management, Process workflow management, Manufacturing planning & scheduling

1 BACKGROUND

The EPC-IT program was established in 2000 to develop a unified framework for Enterprise Process-Centric Information Technology. The targeted industrial sectors included the Precision Engineering (PE) sub-sectors.

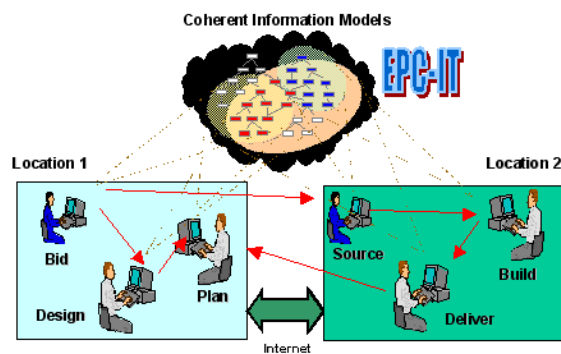


Fig. 1. Business scenario using EPC-IT.

Two early adopters in the Printing and Mould-Making sub-sectors have been identified to help refine the requirements and pilot test the resulting technology. Detailed feasibility studies have been conducted at these two pilot sites.

Based on the concepts and technologies developed earlier for an integrated enterprise system

[1-2], this project focused on the R & D of technologies & methodologies that could provide new capabilities for handling Allocation and Management of Design Resources, On-line Reporting, Capacity Distribution Profile (machine level planning, capacity profile alignment, etc.), Combined Scheduling Rules and Manufacturing View features. These features are critical to companies in the target industry sectors.

2 OBJECTIVE

The main objective of this project is to provide an integrated environment that enables enterprises to plan, manage and control their entire design-to-manufacturing processes, product lifecycles as well as resources efficiently.

The resultant Web-based solution should facilitate enterprise collaboration and lifecycle management in discrete manufacturing SMEs.

It should also integrate the entire business process seamlessly in the target SMEs, from sales to design, planning, production, inventory control and shipping, as illustrated in Fig. 1.

Such capabilities would allow the SMEs to achieve significant competitive advantage with shorter cycle times and higher efficiency.

3 METHODOLOGY

3.1 Business model driven

The innovative Web-based EPC-IT system has been developed based on the business process reference models of selected companies in the printing and mould-making industries.

The reference models, an example of which is shown in Fig. 2, have been established through detailed business process reengineering studies of companies to describe the streamlined business processes, information flows and detail IT requirements [3]. These reference models provide the framework of requirements specifications that define the functional design of the system.

Business process reference models represent the “best practices” of a particular industry sec-

tor, providing abstracts of the general requirements of the system and its business functionality.

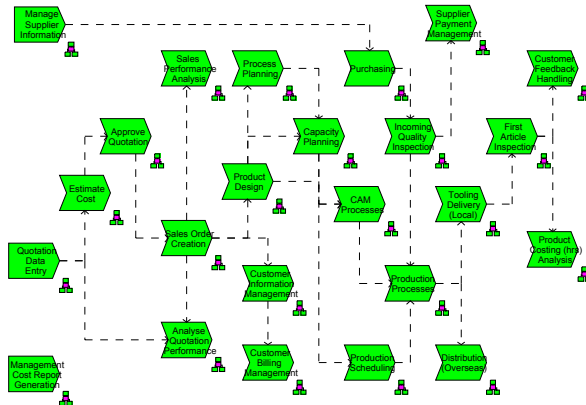


Fig. 2. Reference model for mould-making business.

A reference model for the mould-making business has been enhanced and verified throughout the Software Development Life-Cycle. Such iterative processes are critical in ensuring the practicality and efficiency of the methodology.

3.2 Process centric

Technologies have been developed to enable all the relevant Product, Process and Resource (PPR) information in a company to be defined, linked, updated and managed comprehensively within a single, unified data model as shown in Fig. 3.

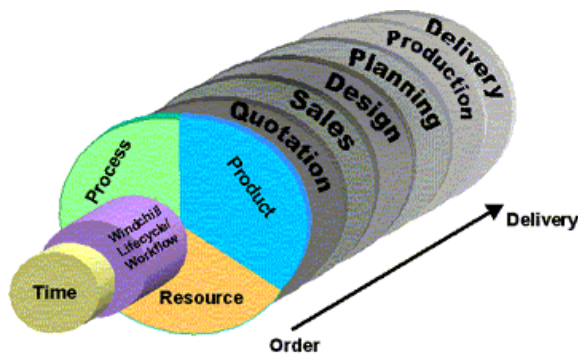


Fig. 3. Integrated information & processes.

This approach enhances the data integrity and revision control capabilities, which are critical in a real manufacturing environment because the PPR information changes continuously over an entire product lifecycle.

A process-centric system ensures that it focuses on the key business processes to integrate all related data and knowledge, so that the imple-

mented business processes can be refined and are more rational and efficient.

Design, Planning and Scheduling activities are some key processes that are effectively supported by the EPC-IT framework. Built on PTC's Windchill™ PDM platform [4-6], EPC-IT provides an advanced and reliable enterprise-wide collaboration environment for manufacturing companies and their partners to handle complex design requirements and to communicate over the Internet [2].

3.3 Lifecycle management

The EPC-IT system takes full advantage of the automated and graphical lifecycle models in Windchill™ [4] to manage the key business objects as they progress from conceptualisation to obsolescence, as shown in Fig. 4.

The lifecycles are iterative and dynamically managed by the system. While an object is in a specific lifecycle phase or has reached a specified gate between two phases, certain business rules (e.g. access control) and workflow can be applied according to the pre-defined criteria.

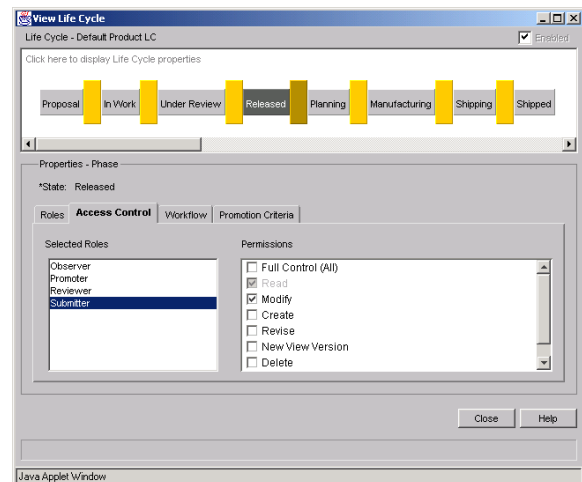


Fig. 4. EPC-IT default product lifecycle.

The EPC-IT system implements lifecycle management on key business objects such as products, parts, job orders and purchase orders, and provides an integrated Graphical User Interface (GUI) to customize or redefine them. This allows the system to simulate the actual dynamic business processes and information processing states in different application scenarios, thus enhancing its internal control. From the application point of view, it ensures that the processing sequence is transparent and controllable by the end-users, who can further refine the lifecycles of the business objects as their business grows

or changes.

Lifecycle management technology enables the EPC-IT system to be adaptive and to respond dynamically to changes in a company.

3.4 Workflow control

Based on the workflow engine provided by Windchill™, the EPC-IT system presents very strong document management and workflow-driven design management features, which simplify the planning and management of design tasks and designer capacities significantly.

The system also applies the workflow management technologies innovatively to CAM management, Purchase Request and Purchase Order processes. This empowers flexible control of business processes, allowing it to be adapted easily to SME's dynamic business requirements.

As illustrated by the workflow example in Fig. 5, if an Approver selects the "Rework" button to instruct an Initiator to refine a Purchase Order further, the system will automatically route the transaction back to the Initiator's work-list and notify him of any comments provided by the Approver. The Approver and Initiator are roles that can be assigned to any specific user.

This technology allows a company's procurement policy to be properly and automatically implemented, and fully customized to fulfil its specific needs.

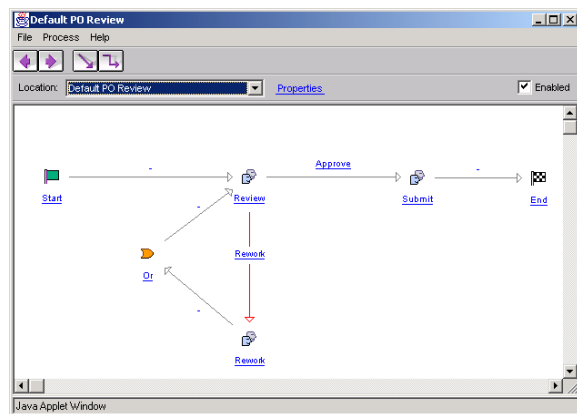


Fig 5. EPC-IT default PO review.

3.5 Flexible configuration

Extensible Markup Language (XML) technologies are widely adopted and enhanced in the system. These allow the behaviours of the different modules to be defined and managed, and the sophisticated functions, objects and relation-

ships among different PPR objects to be specified in a clear but flexible manner.

Web-based services are developed to manage lifecycle processes from cost estimation to quotation, sales, design, purchasing, manufacturing planning, scheduling, production tracking and order shipment.

```

<?xml version="1.0" ??
<FolderConfigs>
  <!-- Beginning of Inventory Management module's folder configuration -->
  <FolderConfig>
    <Classes>
      <class Identifier>ETWarehouse</class Identifier>
    </Classes>
  </FolderConfig>
  <Folder>/Inventory/Warehouse</Folder>
</FolderConfig>
  <FolderConfig>
    <Classes>
      <class Identifier>ETStockControlLevel</class Identifier>
    </Classes>
  </FolderConfig>
  <Folder>/Inventory/Stock Control Level</Folder>
</FolderConfig>
  <FolderConfig>
    <Classes>
      <class Identifier>ETGoodsReceiptNote</class Identifier>
    </Classes>
  </FolderConfig>
  <Folder>/Inventory/Goods Receipt Note</Folder>
</FolderConfig>
  <FolderConfig>
    <Classes>
      <class Identifier>ETGoodsReceiptNoteItem</class Identifier>
    </Classes>
  </FolderConfig>
  <Folder>/Inventory/Goods Receipt Note Item</Folder>
</FolderConfig>
  <FolderConfig>
    <Classes>
      <class Identifier>ETGoodsReturnNote</class Identifier>
    </Classes>
  </FolderConfig>
  <Folder>/Inventory/Goods Return Note</Folder>
</FolderConfig>
  <FolderConfig>
    <Classes>
      <class Identifier>ETGoodsReturnNoteItem</class Identifier>
    </Classes>
  </FolderConfig>
  <Folder>/Inventory/Goods Return Note Item</Folder>
</FolderConfig>
  <FolderConfig>
    <Classes>
      <class Identifier>ETStockCard</class Identifier>
    </Classes>
  </FolderConfig>
  <Folder>/Inventory/Stock Card</Folder>
</FolderConfig>
  <FolderConfig>
    <Classes>
      <class Identifier>ETStockStatus</class Identifier>
    </Classes>
  </FolderConfig>
  <Folder>/Inventory/Stock Status</Folder>
</FolderConfig>
  <!-- End of im folder configuration -->
</FolderConfigs>
    
```

Fig. 6. XML-based configuration sample.

Flexible configuration capabilities are implemented system-wide, from module levels to business flows, features, functions, extensible attributes and user interfaces, as shown in the example in Fig. 6. This provides a mechanism for companies to tailor the system to meet their unique business requirements, and to align it with their business practices and organizational structures.

Various services are provided for object configuration, relationship configuration, template configuration, report configuration and system configuration.

4 FEATURES AND FUNCTIONS

The resultant EPC-IT system offers a very powerful set of integrated features and functions, as depicted in Fig. 7.

- Cost Estimation and Quotation Management
- XML-based templates are used to define the business rules and formulas for cost estimation

- Quotations can be generated based on cost estimates of all relevant items, and routed for reviews and approvals
- All in-coming requests for quotations (RFQs) and documents can be managed with revision control, supported by multiple-iterations and related branching information.



Fig. 7. EPC-IT features and functions.

- Sales Order Management

- Customer orders can be linked to corresponding sales quotations
- Job Orders are generated from Sales Orders and released to design, planning or purchasing respectively
- Shipping plans can be created and managed along with invoicing and billing details

- Integrated Design and CAD/CAM Document Management with Revision Control

- Popular CAD software can be integrated, allowing all design specifications, CAD files, product structures (Bill-Of-Materials) and other important documents to be managed with effective revision control
- Product BOM can be extracted directly from a 3-D CAD model (with optional CAD adapter) to enhance materials planning
- Workflow-driven design tasks can be planned and assigned to designers based on managed designer capacity
- CAM design information & processes can be managed under workflow control

- Product Visualization

- Embedded visualization technology enables viewing, checking and annotation of 2-D and 3-D CAD models, as well as common office documents, without using native software applications

- Enhances collaboration among internal and external project team members

- Purchase Order Management with Revision Control

- Purchase requests can be created directly from material lists generated by planning function for specific jobs, or for purchasing of ad-hoc or inventory-controlled items
- Purchase orders can be created directly or converted from purchase requests, linked to supplier information, managed and controlled by workflow for approval cycles

- Flexible Route Planning

- “Make-or-Buy” decisions can be made readily based on the extracted BOM
- Routing plans can be specified based on customisable templates and modified easily for parts to be made

- Capacity Planning & Production Scheduling

- Released jobs can be checked against available machine capacities to ensure due dates can be committed
- Daily production schedules can be automatically generated to assign specific machines to planned operations according to preferred scheduling rules
- Operations can be manually adjusted and re-prioritised if necessary
- Combined Rule-based Scheduling allows interactive adjustment involving new rules, changes in rule sequence, and changes in scheduling tolerance values
- Suitable for dynamic environments, where changes are frequent or when accurate data is not available

- Job Tracking from Design to Fabrication to Order Shipment

- Up-to-date status of design, NC program preparation and shop floor production can be tracked, down to machine level, enhancing responses to changes

- Shipping & Delivery Order Management

- Business documents, including cartons, packing instructions, shipping items, delivery orders and packing lists, can be generated and managed effectively

- Inventory Control and Management

- Goods received, returned, stock adjustment, distributed warehouses and inventories of

standard parts, raw materials and finished goods can be managed to support materials planning, procurement, production planning and shipment planning processes

- Job-based inventory and safety stock levels can be managed effectively to reduce stock holding risks
- Customer/Vendor Library Management
 - All external contacts and account details, including customer and supplier information, can be managed efficiently according to their respective roles
 - Contact details can be linked to and referenced by sales or purchase orders, enhancing customer and supplier relationship management
- Resource Definition and Management
 - Resources such as work centres, machines, employees, production shifts and working calendars can be defined easily
- Financial Information Management
 - Critical financial information can be captured for management and sales analysis
 - Work-In-Progress reports can be generated to monitor the overall financial performance of both in-house and out-sourced jobs
- Advanced on-line Security Techniques
 - Access control at the function level, feature level, role level and database level is provided besides the normal Internet based security regimes, e.g. firewall, SSL or HTTPS
- Online Report Generation
 - Customisable XML-based specifications and templates can be created to generate reports based on Microsoft® Excel spreadsheet formats
- Native Web-based architecture promotes collaboration over the Internet
 - Rich client Java applet techniques are used to support human-interactive activities like planning and scheduling processes
 - Thin client JSP techniques are designed to facilitate fast processing of information
 - XML-based technology provides a means for information exchange among product design, development and other business processes, as well as with other systems

5 RESULTS & DISCUSSION

The EPC-IT system has undergone two stages of pilot testing in a mould making company, and successfully deployed in July 2003.

As anticipated, there were numerous requests for changes during the pilot testing and deployment phases. For example, users had requested for changes to the system design and purchasing workflows in order to align with their current procedures, and to include some new attributes in various modules of the system to capture their company-specific information. For most other enterprise systems, the implementers would need to analyse the impact, change the database schema or customize the program to adapt to the changes. These would require several days, weeks or months of effort. Some may not even accommodate the changes because of the lack of flexibility in their systems.

On the other hand, the changes were easily addressed within EPC-IT. Its workflow-driven and flexible configuration technologies provide unique strengths and capabilities, allowing it to be adapted easily to dynamic business environments.

A human planner would typically use spreadsheets to specify the manufacturing plans for a product after its design has been completed. With the EPC-IT system, previously disparate data are now fully integrated with Product Design, Routing Planning, Manufacturing Planning, Production Scheduling and Purchasing functions. This allows planning, scheduling and purchasing of materials to be performed while design is still in progress. Early planning and access to critical design data have resulted in significantly higher efficiency, lower risks in manufacturing, and shorter overall job shop scheduling cycle time.

6 CONCLUSION

The EPC-IT system is an innovative Web-based solution that enables enterprise-wide collaboration and lifecycle management in discrete manufacturing SMEs.

Advanced technologies and methods have been developed, enhanced and further refined in this project. The resulting EPC-IT system has seamlessly integrated the entire business process in a mould making company from sales to design, planning, production and shipping. This will increase its competitive advantage with shorter cycle times and higher efficiency.

The system and its methodologies, especially the business reference models & rapid deployment approach, have been validated in a real business environment. The experience and lessons gained from the research, development and implementation of an enterprise-wide IT system have been invaluable.

7 INDUSTRIAL SIGNIFICANCE

EPC-IT is currently the only known Web-based solution that integrates the entire business processes of SMEs in the target industry sectors.

Since Jul 2003, the software system has completed pilot testing and successfully deployed at a mould making company. It will later be tested and deployed at a second pilot site, a printing company. Other companies are being identified as potential early adopters.

This innovative Web-based system enables engineering SMEs such as mould & die, tooling, precision component and equipment manufacturers to streamline and integrate their entire design-to-manufacturing processes, thereby achieving significant improvements in operational efficiencies. It supports design-centric activities and enhances enterprise collaboration from Quotation to Sales, Design, Routing Planning, Production Planning, Scheduling, Inventory Management, Purchasing, Job Tracking and Shipment.

EPC-IT enables SMEs to plan, manage and control their entire business processes, product lifecycles and production resources efficiently.

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