A paradigm for ERP and BPR integration

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In order to sustain a competitive edge in this global manufacturing era, enterprises need to adopt appropriate improvement schemes. Two widely-used tools have been Enterprise Resource Planning (ERP) and Business Process Re-engineering (BPR). ERP is identified as the most applicable information system for the modern manufacturing industry. In addition, many BPR practitioners have identified the use of information technology (IT) as a critical factor for the success of BPR. Nevertheless, research into IT for BPR and hence ERP is limited. One of the major reasons why the ERP system has not been implemented successfully is the inappropriate use of design and implementation methodology employing the modern BPR concept. Accordingly, in this paper, the authors propose a conceptual model called the Hierarchical Design Pyramid (HDP), to implement ERP under an enterprise re-engineering (BPR) context, using an integrated structured and object-oriented tool to design a novel manufacturing system in a total quality environment. The proposed model aims to provide a basis for manufacturers to implement ERP in a systematic manner.

1. Introduction

Most manufacturers today are so used to working according to conventional methods that they rarely ask themselves why they have to perform tasks in such ways. As a result, they are becoming less and less competitive when dealing with unpredictable changes. This situation is worsening since the business world is becoming more and more complicated and globalized. Enterprises need to adopt radical improvement schemes in order to sustain their competitiveness in this global manufacturing era. Consequently, Business Process Re-engineering (BPR) has become an extremely popular topic nowadays (David and Henry 1995).

Many BPR practitioners have indicated that the application of IT is critical to the success of BPR (Tapscott and Caston 1993, Kettinger and Grover 1995). Hammer (1993) stated that, ‘A company that cannot change the way it thinks about information technology cannot reengineer’. He described the implementation of state-of-the-art IT as an essential enabler toward re-engineering. Manganelli and Klein (1994) noted that the appropriate methodologies of re-engineering should feature both the empowerment of human resources and the use of IT as the prime enablers of radical changes. Davenport (1993) explained that the IT process has impacts in terms of organization streamlining/simplification, capturing and distributing, coordination, monitoring, analysis and decision making, and parallelism, enabling process change.

Tapscott and Caston (1993) describe three fundamental shifts for an organization in the application of computers in business, each affecting a different level of business

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opportunity. They state that IT enables enterprises to evolve from a ‘high-performance team structure’, to function as an ‘integrated business’, then to develop further new relationships with external organizations, becoming an ‘extended enterprise.’ Venkatraman (1994) proposes a similar framework that breaks an IT-enabled business transformation into five levels. The level of potential benefits achieved by adopting different IT strategies is proportional to the degree of business transformation undertaken. According to some of the literature, the use of IT in BPR has promoted a successful rate of implementation. However, the literature only discusses the significance of IT in re-engineering but no generic model has been proposed to design and implement an ERP system under a BPR context. In this paper, the authors propose a conceptual model, which encompasses the management concerns and the technology aspects, to provide a guideline for the implementation of IT with quality in a systematic manner.

2. Modern operations management approaches

With the accelerated advancement of technology, a manufacturing technology that works to drive down production costs and an IT that enables massive amounts of data to be transmitted and processed at an unprecedented rate, have changed many of the conventional ways of doing business. Some modern operations management methods have been proposed and investigated by researchers. Those that have received wide attention are briefly discussed, as follows.

BPR (Business Process Re-engineering)—the idea of BPR first sprang from Michael Hammer in his article (Hammer 1990), ‘Reengineering work: don’t automate, obliterate’. Manganelli and Klein (1994) define BPR as the rapid and radical redesign of strategic, value-added business processes, and the systems, policies, and organizational structures that support them—to optimize the workflows and productivity in an organization. They offer a definition that focuses on optimizing workflow and productivity in an organization. Hammer and Champy (1993) define re-engineering as ‘the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed’.

ERP (Enterprise Resources Planning)—a game plan for planning and monitoring all of the resources of a manufacturing company, including the functions of manufacturing, marketing, finance, and engineering (Wight 1993). ERP represents the application of the latest IT to the MRP II (Manufacturing Resources Planning) system. This is recognized as being an effective management system (Ormsby et al. 1990) that has an excellent planning and scheduling capability offering significant gains in productivity, dramatic increases in customer service, much higher inventory turns, and greater reduction in material costs. These technology innovations include the move to relational database management systems (RDBMS), the use of a graphical user interface (GUI), open systems and a client/server architecture (Robert 1996).

TQM (Total Quality Management)—programmes and initiatives carried out within a company that emphasize incremental improvement in work processes and outputs over an open-ended period of time (Davenport and Beers 1995). Pfau (1989) defines TQM as an approach for continuously improving the quality of goods and services delivered through the participation of all levels and functions of the organization. Deming (1986) lists 14 points that are essential to establish a TQM
environment and the seven deadly diseases that must be avoided in order for TQM to succeed.

JIT (Just In Time)—approaches to planning and control functions with the aim of minimizing waste in manufacturing, a broad philosophy of pursing zero inventories, zero transactions, and zero disturbances (Vollman et al. 1992). Monden (1993) simply defines JIT as ‘producing the necessary items, in the necessary quantities at the necessary time’. Under different terminology, including Zero Inventory (Hall 1983), World Class Manufacturing (Schonberger 1986), Lean Production (Womack et al. 1991) as well as the Toyota Production System (Monden 1993), JIT manufacturing systems have been developed with numerous techniques to support the basic principle.

These approaches to creating manufacturing excellence are not mutually exclusive in nature. For instance, there are good opportunities for ERP and JIT working complementarily to bring about good manufacturing management. On the other hand, there exist extended debates as to whether BPR is an extension of TQM, or vice versa. This paper is not involved in giving details of distinguishing which is which, even if this were possible after so many researchers have raised their points and/or challenged one another’s theories. In fact, the authors propose a model—Hierarchical Design Pyramid (HDP)—which aims to integrate the modern operations management method beyond anecdotal evidence.

3. Hierarchical Design Pyramid (HDP) model

Several methodologies are available for the design and modelling of an ERP system. Zhang and Alting (1991) suggested that the approach through structural modelling or the systems approach is the first step towards the application of IT in manufacturing. Hargrove (1995) applied the structural approach to the design and planning of machine fixtures. Cheng and Robert (1996) used an IDEF model to develop a knowledge-based manufacturing information system. They have shown a successful example for system modelling using a structure methodology. In general, structural methods such as SSADM and IDEF are inadequate for problem domain analysis with natural concurrence. Therefore, some researchers (Coad 1991, Jacobson 1992, Martin and Odell 1992) propose object-oriented methodology (OOM) to analyse and design the software systems to supplement the conventional structural methods. Nevertheless, very little of the literature has mentioned the relationships between business process re-engineering and the design of an ERP system. Accordingly, the authors propose a new design model—HDP (figure 1)—which integrates the technological modelling and the BPR together with the TQM concept.

The basis of our model is to develop a paradigm that provides a culture supportive of change through IT enablement, quality management and internal and external communication networking which facilitates the implementation of effective process and change management practice through an entire company. In our model, we integrate the structural and object-oriented approaches; these should be complemented with each other through a step-by-step systematic integration pattern. The systematic approach will ensure the design and implementation of a successful ERP system. The generic HDP model, which is composed of two major building blocks—IDEF0, and Object-Oriented Modelling—is used to achieve the ERP model. OOM by Booch (1994) can be easily used to maintain the
structure and behaviour of the objects of the IDEF design that is derived from the ERP model.

In terms of BPR, our model is incorporated with the concept of Hammer and Champy’s (1993) and includes four key elements, namely fundamental, process, radical, and dramatic. These four elements differentiate re-engineering in our model from other improvement approaches as follows.

- **Fundamental**—Fundamental implies that everything which the organization has been doing—every assumption, every reason, every process and every activity—is challenged by asking why it should be done in such a way. This concept enables the refinement of system specifications by continuously asking ‘why’. The set of system specifications is primarily important to the accuracy and consistency of the business rules and logic in the ERP model.

- **Process**—Process is defined as a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer. Due to the success of the division of labour in an organization, people become more concentrated on the tasks performed around them. Then, in the system
development stage, the personnel can focus on their own tasks by using the structural methodology (IDEF0). The components in IDEF0 such as input, output, control and mechanism can be defined precisely.

- **Radical**—The major difference between continuous improvement and re-engineering is that the latter is not about improvement at all, but about re-invention. The idea of re-invention is crucial to the Object-Oriented paradigm. The conventional way of doing something may not be the most appropriate way. In OOM, the object models and the relationships between them can be elaborated upon in the foundation stage.

- **Dramatic**—The intention of re-engineering is to achieve quantum leaps in performance. It is not about making marginal or incremental improvements, the achievement of which can be brought about by other more conventional methods. Regarding our proposed model, the ERP system can provide manufacturers with a significant improvement in terms of inventory level, unit production cost, quality, etc. The HDP model also contributes to an effective way for system development and implementation by the integration of structural and object-oriented approaches.

TQM furnishes the company with a quality environment during the whole re-engineering project. A quality culture is essential to the successful implementation of all new technologies within a company. Regarding the system modelling, the HDP concept aims to adopt the OOM by capturing all the necessary states, methods, and the relationships between classes from the IDEF0 structural design. During the design phase of IDEF0, some elemental information such as input, output, control, mechanism, process and specification are extracted from the ERP model. This information is essential to the confinement of object models by reviewing the states, methods and the relationships between classes. Therefore, the IDEF0 design can be treated as the design layer while the OOM is the implementation layer. The details of system implementation by using OOM are not described because of space limitations, so only the system modelling will be discussed in the following sections.

4. **Methodology**

Typical structural analysis methodologies are SADT (Structured Analysis and Design Technique) by Douglas T. Ross of SoftTech (Ross 1977, 1985), SSADM (Structured System Analysis and Design Methodology) by Learmonth and Burchett Management Systems and the Central Computer and Tele-communications Agency (Cutts 1991), IDEF (ICAM Definition) methodology, DFD (Data Flow Diagram) approach (DeMarco 1979, Gane and Sarson 1979), and STD (State-Transition Diagram). In the HDP methodology, IDEF is selected to be the core development tool. IDEF, derived from the US Air Force Integrated Computer Aided Manufacturing (ICAM) (Wisnosky 1987) initiative, is a structured analysis and design method based on graphic and text descriptions of functions, information and data. The IDEF method is widely understood and well documented (Hill 1995, Benjamin *et al.* 1993, US Air Force). The method originally defined by the ‘Architects Manual’ includes guidance for modelling, together with rules for model syntax, diagram and model format and text presentation, as well as structured model validation, document control procedures and interview techniques. Figure 2 illustrates the IDEF0 general model representation. The data dictionary provides a
means of easy access to the information, i.e. data and objects within the system in the diagram hierarchy.

In the HDP model, a complete IDEF0 model of the ERP system is produced in an interactive process. This is done by determining the boundaries of the system to be modelled. The main entities and data that pass to and from the system must be identified. The first draft of a top-level A0 diagram can therefore be produced. It is important to remember that the IDEF0 model may only be developed upon a defined perspective. If the focus is lost, the quality of the model is reduced. From this defined perspective, the 'view' is decomposed and a consistent decomposition can be developed. Furthermore, the purpose of the model must be clarified on the A0 diagram. The level of detail depends on the defined purpose. This is thus the criterion for determining when to stop decomposing the model. The diagrams that have been developed as first drafts are circulated around the relevant departments, where each department checks and judges how accurately their parts of the system have been modelled. The inputs received from individual departments act as feedback information so that the author can make amendments. The cycle is then repeated several times until the model is completed and approved. In essence, the IDEF0 modelling technique requires company-wide time and resource commitment in order to produce a manufacturing system (Colquhoun et al. 1989), a requirement that can only be met though the TQM process, and substantial improvement by re-engineering the existing manufacturing system.

5. The ERP system model

Figure 3 depicts the hierarchical structure of the Generic ERP model derived from the proposed HDP model. This is generated by the Design/IDEF software and illustrates the node tree decomposition of the model, giving the relevant titles and page numbers.

All the activities involved in the design of an ERP system are modelled by first defining the most important Inputs, Outputs, Control functions and required Mechanisms (IOCM). Figure 4 shows the top-level diagram, A0 of the model.

5.1. ERP system planning

With reference to figure 5, the project begins with system planning. This is a blueprint that organizes the resources and directs future activities involved in the
The three activities consist of Project Scope and Goal Definition, Feasibility Study, Final Project Plan. The details can be elaborated as follows.

5.1.1. Project scope and goal definition

An initial study of the business operations is conducted in order to arrive at a problem definition. The project group is then able to define the scope of the project.
and settle for a certain set of goals against which the alternative design is evaluated. The operating requirements, data requirements and the processing requirement is also obtained as input for the feasibility study.

5.1.2. Feasibility study

The constraints and controls of the project are located. These are carefully examined in order to decide whether the preliminary requirement defined at the earlier stage can be fulfilled.

5.1.3. Final project plan

The plan specifies the scope, system performance, timing and budget allocated to the project. A timetable is produced to organize and control the resources and the activities.
5.2. Process re-engineering

This stage of process re-engineering calls for study and redesign of the existing state of affairs in a given business area of the enterprise. It begins with preliminary analysis and the business operations and problems are studied in greater detail. The process re-engineering includes four steps which are elaborated upon as follows.

5.2.1. System analysis

The system designers must completely familiarize themselves with the current working system by auditing its flexibility, reliability, accuracy, efficiency and connectivity. Any problems that are inherent in the system can be fully understood and clearly defined. Modelling techniques are employed to map out the logical flow of the processes involved in the system.

5.2.2. Process re-thinking

This involves recognizing potential solutions, and then seeking and recognizing obvious or latent problems that may be solved. The system designers should query the assumptions that underlie current business operations in order to generate new methods. In this way, a set of new system rules and processes can be achieved for process benchmarking.

5.2.3. Process benchmarking

Benchmarking is usually considered a continuous improvement tool. In our model, it can be used to gain information regarding a company’s relative position in key business processes and core competencies. The project group can use this technique to create an industry context for the goals being set. This provides the company with examples of best practices in terms of new processes and the approach to implementation.

5.2.4. Simulation

Simulations are used to visualize and evaluate the redesigned processes generated by process re-thinking. This provides re-engineers with an appropriate tool for evaluating new processes. Discrete-event computer simulation and animation can be accurately applied in understanding processes. After the evaluation, a new system description including user requirements and specifications and defining what needs to be done, given the support of more advanced information systems, is produced and is used in the system design stage.

5.3. ERP system design

Figure 5 shows Node A3 of the ERP system, and the decomposed page of this activity is shown in figure 6. The descriptions of the activities involved in node A3 are listed below.

5.3.1. Analyse and identify requirements

This is a very important area of HDP since all parties concerned must be certain what they wish the ERP system to achieve. This process of specifying the requirements can be quite exhaustive, but its importance should not be underestimated,
considering the work and expense that will be incurred following the requirement definition.

5.3.2. Analyse and review the current system

The system designer should research as much as possible into already existing systems, in order to avoid spending time developing something that is already commercially available at a reasonable price and to learn about design ideas he or she has not previously thought of.

5.3.3. Initiate ERP design

When the preliminary work is completed and the requirement model generated, one cannot begin the system design phase at this stage. Similar to the project model required during the initial organization, the design phase must be properly initiated. The decomposed page of Node A33 is shown in figure 7. The activities involved in the node A33 are design generic ERP functions, design system database structure and logical process design, and the details as listed below.

Design generic ERP functions. Some of the functions, which are critical to an effective ERP system, and must be addressed, are shown in figure 8. These system functions are listed in the node tree (figure 3). Due to limitations of space, only two functional designs (design planning system and design production system) are illustrated here.

Design planning system

This includes three planning systems, which are the Design Master Scheduling Planning System, the Design Capacity Requirements Planning System, and the
Design Material Requirements Planning System. The design criteria and the inter-relationship between these systems are described as follows.

(1) **Design master scheduling planning system**

The function of this system/module is to help the master scheduler develop a realistic production schedule that provides a level plant load. This helps to develop a
plan of resources and compares it with the resources available. As a result, inventory investment can be minimized by matching the master production schedule to actual and forecast demand. Customer service can be increased by providing accurate, time-phased production that becomes available as promised. Critical resource availability against requirements can be monitored to ensure that the production plan is realistic.

(2) Design capacity requirements planning system

In the capacity requirements planning (CRP) system, some interactions can be identified. To cite an instance, work order control and production activity control provide the time phased work order input needed to project the work centre load from work-in-process. In addition, the planned order input for manufactured MPS items in CRP is supplied by the master scheduling. On the other hand, the material requirements planning module provides the planned order input for manufactured items from regenerative or net change MRP schedules.

(3) Design material requirements planning system

The purpose of this system is to provide the information and control for the company to plan and manage effectively the production and execution of the sales forecast and master schedule. The information derived from this system not only indicates the material requirements and order processing necessary to meet a company’s plan, but also assists management in planning and monitoring cash flow. Specific management objectives are (i) to minimize the amount of inventory on-hand and on-order to support the master production schedule; (ii) to plan purchases and production with the correct timing and priority; and (iii) to determine the cost impact of executing the master production schedule.

Design production system

(1) Design job order control system

The aim of this module is to allow the user to tie production activity and costs to a job. Production budgets and job estimates can be built from the cost data defined for the components and assemblies to be used in the job. Detailed cost reporting can be provided to monitor all costs charged to the job. Specific management objectives are (i) to provide realistic job cost budgets and estimates; (ii) to control the costs of jobs; (iii) to monitor the progress of jobs through the production processes; and (iv) to provide actual cost variance reporting.

(2) Design work order control system

The work order control system is used to provide a complete and comprehensive method for production costing analysis. It can easily be structured for multiple levels of manufacturing which involve tracking from the component part level to the finished product. In addition, it tracks the various operations, procedures, and labour.

(3) Design production activity control system

Work Order Control schedules open operations from work orders while Capacity Requirements Planning uses shop scheduling and the planned orders from MPS and MRP systems to calculate the capacity plan and capacity load. Therefore, the production activity control system enables the user to monitor the progress of
operations through the production facility. Dispatch reports can be produced using several priority methods.

(4) *Design purchasing/receiving system*

The purchasing/receiving system maintains information about approved vendors and approved manufacturers, purchase orders for multiple parts and multiple scheduled deliveries per part, receiving, receiving inspection, vendor shipments, and buyer performance. This system accumulates information for both purchasing and vendor performance evaluation. Vendor information is placed into the purchase order. The purchase order data are placed into the receipts and, finally, the receipt information is transferred into accounts payable receipts and material inventory movements. Moreover, this also consists of a number of ‘sub-systems’; purchasing, receiving, vendor shipments, and purchasing history.

(5) *Design total quality control system*

Total quality control is particularly important to the design of the ERP system which also forms a part of the TQM process. Specific management objectives are (i) to control incoming and in-process material inspection, to ensure that material is inspected to proper inspection criteria and the correct sampling plan for the part or vendor; (ii) to maintain current inspection specifications and sample plans for use in inspecting material; (iii) to manage vendors through approval for supplying parts and certification allowing the inspection to be by-passed; and (iv) to allow vendor selection through vendor analysis based on quality, price, and delivery performance. All the management objectives are well documented in the quality system manual of the company.

(6) *Design inventory management system*

This system is designed to handle three types of items namely (i) manufacturing items, (ii) trading goods and (iii) fixed assets. The design of this system seeks to maintain accurate information on the quantity, location and value of all inventory items. The aims are to reduce inventory investment and handling costs and to improve customer service through better delivery schedules. By improving the integrity of inventory data, the basis for better material planning and control is established. The system specifically aims (i) to increase inventory turnover and reduce inventory investment with a corresponding reduction in handling costs; (ii) to improve customer service through shorter lead times and reduce late customer deliveries, thereby improving a company’s competitive position; and (iii) to improve the integrity of inventory on-hand data and provide a basis for better material planning and control.

*Design database structure.* Referring back to figure 7, the database structure is the vital part of the ERP system in which systems must interface with each other, in order to provide critical information. For example, the inventory database must be updated as soon as components are withdrawn from or returned to stock. The work in process (WIP) system must interface with the inventory database to track the location and the status of assemblies in storage. Process planners should access the inventory database to ensure that only materials available are assigned for production. Data flow diagrams (DFDs) (Ashworth and Goodland 1990) were introduced to capture the flow of information because IDEF0 cannot capture the in-
formation flows between several functions simultaneously. A data flow diagram is stored in the data store which shows the data movement within the system and yields a set of interested data items. These items are logically related to one another. The relationship between these data items is modelled by an Entity Relationship diagram (ER diagram) (William et al. 1991). After the consolidation of the ER model, mapping of the ER model to the relational model can then be launched.

Design logical process. Referring back to figure 7, this process outlines in detail the operations that the system performs either in response to an enquiry or retrieval. The software programme will then be implemented based on the process outlines structured by adopting the OOM as stated in the HDP model.

5.4. System evaluation

Referring back to figure 5, different proposals of ERP are evaluated during this stage. To accelerate such a time consuming and costly process and promote accurate performance data, simulation is recommended. In the evaluation process, the system design should not overlook the compatibility of the ERP system with other information systems currently running in the company. A final decision can then made as to which alternatives are to be chosen and implemented.

6. Conclusions

In this research, the authors propose an HDP model to design and implement an ERP system under the macroscopic context of business process re-engineering with a total quality approach. The design methodology proposed in this paper can be summarized into two major phases. The first phase is to design a structural ERP model by using the IDEF0 design tool, together with the node index of the model. Note that only those activities closely associated with ERP are considered in this paper and that, for reasons of brevity, only their accompanying discussions are provided. The second phase is to model and implement the design by OOM. The details of programming and modelling illustrations have not been included in this paper because of space limitations, and these researches will be reported in a forthcoming paper. A systematic approach which integrates technology and human factors is essential for the ERP to be successful. Hence, the BPR and TQM of the model being implemented by any company-wide ERP project are not to be underestimated. The TQM concept is proposed for incorporation into our model so as to establish a good company culture for the project implementation. In conclusion, the significance of our model is substantial, since it enables enterprises to build an effective information system with a novel approach that can ensure competitive advantages in an ever-changing global environment that embraces the latest array of modern manufacturing system concepts.

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