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The role of information technology in business process reengineering

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Abstract

This paper discusses the role of information technology in business process reengineering (BPR). BPR was introduced in manufacturing/service industries with the objective of changing the management of the supply chain. In manufacturing, the nature of material flow determines the type of information and decision support systems required to achieve system integration and hence the overall effectiveness of the system. A conceptual model has been developed in this paper to illustrate the role of information systems in BPR and the type of information systems required to integrate functional areas in manufacturing. Hammer's (1990) message "Reengineering work: don't automate, obliterate" stresses a radical process simplification as the way to reduce time and cost, and to eliminate or at least simplify processes, not just speed them up. There has been tremendous interest on how to simplify the process and hence the information system required for effective management of material flow in manufacturing. The implementation of BPR using innovative application of information technology (IT) aims at flexible, team-oriented, and cross-functionally co-ordinated management. A framework has been presented in the paper to design a more effective BPR system with the help of advanced IT. Finally, a summary and conclusions are presented.

Keywords: Business process reengineering; Information technology; Framework for BPR system

1. Introduction

Business process reengineering (BPR) concerns the fundamental rethinking and radical redesign of business processes to obtain dramatic and sustaining improvements in quality, cost, service, lead time, outcomes, flexibility and innovation. A group of related tasks that together create value for a customer is called a business process. Common corporate goals have been (a) customer satisfaction, (b) return on investment, and (c) market share (Hewitt, 1995). These require process inter-dependencies and system dependencies that are established through integration of various business processes. The basic objective in BPR is to develop integrated inventory management and logistics strategies and processes to ensure their implementation through procedures and systems across the company based on the business process.

A business process can be identified as the type of commodity that flows through the system. For example, a product development and its transformation into a final product can be viewed as a process. BPR focuses on the whole process, say starting from product conceptual stage to final product design. Process focus provides the opportunity to reengineer the process or radically reduce the number of activities it takes to carry out a process with the

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help of modern IT (Hammer, 1990; Hammer and Champy, 1993; Peppard and Rowland, 1995). New developments in IT such as multimedia, image processing and expert systems can be used to reduce the number of non-value added activities. Organizational restructuring including job redesign, can be used to improve the delivery process of goods and services.

Process simplification is the first major step in BPR. Therefore, a process improvement team should be established with an objective to analyze the whole process and then to identify non value-added activities such as storage and inspection, and eliminate them. The delivery process emphasizes cross-functional performance rather than encouraging departmental optimization and the consequent system-wide sub-optimization.

The role of IT in re-engineering can be viewed from two perspectives: (i) the role of the IT function (e.g. Internet, Multimedia, EDI, CAD/CAM, ISDN), and (ii) the role of the technologies themselves (e.g. CD-ROM, ATM, fibre optics). The IT have played a vital role in the success of the overall re-engineering initiative. Information management throughout the company should be encouraged to develop skills in computer-aided systems engineering (Davenport and Short, 1990; Hewitt, 1995).

Realizing the importance of IT in BPR, an attempt has been made in this paper to understand first the concept of BPR and its importance to improve the competitiveness of firms and second the role of IT in BPR. Finally, a framework has been presented that provides a stage-wise design of a BPR system. The organization of the paper is as follows: Section 2 presents the concept of BPR. Advances in IT are discussed in Section 3. The role of information systems in BPR is discussed in Section 4. Section 5 presents a framework for the design of BPR system. A list of suggestions for BPR is presented in Section 6. The final section contains the conclusions of the paper.

2. Business process reengineering (BPR)

The keywords for the BPR are fundamental, radical, dramatic and process. The business process has to undergo fundamental changes to improve productivity and quality. Radical changes, as opposed to incremental or adjustment of what exists, are made to create dramatic improvements. Re-engineering is not about fine tuning or marginal increases. It is for ambitious companies that are willing to do whatever is necessary to improve performance significantly. Most companies are function- or department- and not process-oriented. Often many people are involved in order fulfilment, but no one person tracks a product and can report the status of an order directly. Reengineering makes one individual responsible for a complete process (Self, 1995). There are factors that will prevent re-engineering and hence innovation and growth: (i) Correcting the process instead of changing it, (ii) loss of nerve, (iii) the barons, (iv) change of company champion, (v) settling for minor results, (vi) culture, attitudes and skill base, (vii) skimping on resources, and (viii) pull back when people resist change. Childe et al. (1994) have presented frameworks for understanding BPR. BPR focuses upon the sequence of activities which form various processes involved in doing business. BPR should enable firms to model and analyze the processes that support products and services, highlight opportunities for both radical and incremental business improvements through the identification and removal of waste and inefficiency, and implement improvements through a combination of IT and good working practices.

A conceptual model explaining the major elements of BPR is shown in Fig. 1. As discussed earlier, an effective delivery process system can be achieved by BPR. BPR requires organizational restructuring with the help of simplification and standardization, and IT such as Multimedia, Internet, MRP II, CAD/CAE, Electronic Commerce (EC) and Concurrent Engineering (CE). The organizational restructuring by standardization and simplification eliminates barriers for a smooth flow of information and hence an efficient flow of materials along the supply chain. The smooth flow of information can be facilitated by the use of various IT to improve the integration of various functional areas. The basic aim of BPR is to deliver quality goods at competitive prices in a timely fashion. The manufacturing system as well as the enterprise structure should be modified emphasizing *simple co-ordination* of the basic business processes in the chain from the suppliers to the customers, as opposed to the existing complex structures of the functional differentiality hierarchies. The behavioural changes should precede the reengineering of

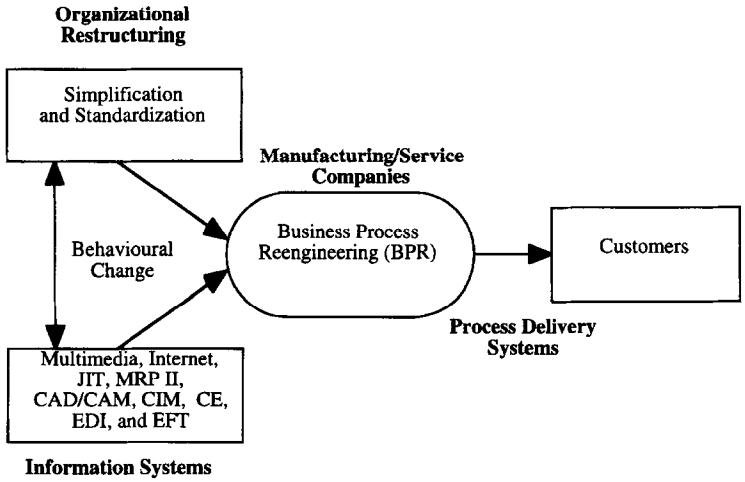

Fig. 1. Major elements of business process reengineering.

business processes. Therefore, issues such as training and education, employee empowerment, team work and incentive schemes play a major role in reengineering business processes.

Business performance can be improved by mass customization as well as by simplification. This requires rapid development, flexibility in management and process-based systems. In order to reengineer the business process, the internal and external process capabilities such as product development, production, distribution, suppliers and markets, and inter-organizational relationship especially in global manufacturing environment need to be integrated. Also, this helps to achieve lean production through the integration of production activities into self-contained units along the production flow. IT is an important element in such an integration. The techniques such as time-based analysis, systems re-engineering tools and IT can be applied to supply chain management as well as to the customer administration cycle (order taking to cash collection), product design cycle (concept definition to product availability), human resource development cycle (skills need identification to training completion), and virtually every other process within an organization. The appropriate handling of the *human motivational reactions* to change is unquestionably as important in the successful introduction of radically new method of working as are the technical aspects of the process design.

Due to growing concern about the global competitiveness, several initiatives have been undertaken to enhance the competitive position of manufacturing/service companies. BPR is a structured approach to analyze and continually improve fundamental activities, such as manufacturing, marketing, communications, and other major elements of a company's operation (Elzinga et al., 1995). Collins and Reynolds (1995) presented the experience of Microsoft Ireland's reengineering program and explained how to solve inventory problems effectively. The company has solved the inventory problems in supply-chain by using on-line stock control with advanced IT. Kenlaw (1995) explains how IBM's Sales Force Transformation (SFT) business unit provides professional services to Fortune 2000 customers seeking to *automate* sales and marketing functions. Increasingly sales managers are looking for an integrated system that links front-end departments to manufacturing resource planning and enterprise resource planning systems. By time-based selling, IBM has developed a system to eliminate paper or duplicate order-entry procedures with an objective to increase the accuracy of those orders and to streamline contract writing and signing. All these imply that BPR has the scope for applications in manufacturing/service organizations and IT is an integral part of BPR.

According to Self (1995), there are three things a manufacturing company needs to do so as to be able

to compete effectively: (i) offer an efficient and well-automated manufacturing system which is capable of giving the company an advantage over competitors; (ii) provide a co-ordinated method of meeting the order-winning criteria; and (iii) re-engineer the company's processes in such a way that the product meets order-winning criteria and maximizes profit. This area has the potential for future research and applications. Many believe that technology transfer, in the form of automation, is the sole answer to business problems. Nevertheless, automation does get some jobs done faster, but no fundamental or radical improvement in performance results without procedure or process changes. Therefore, radical improvements through factory innovation have more to do with a company's ability to change its processes and practices itself than simply automating (Hammer and Champy, 1993). For companies reengineering, the altering of company's in-house procedures and practices, is an essential prerequisite to effective innovation and growth. More often a change in the industrial culture and infrastructure should be necessary before investment in new plant can take effect.

BPR is a top-down, process-driven approach managed by senior executives which aims to improve the performance by radical changes in the system over the short term (Ardhaldjian and Fahner, 1994). Companies usually have to meet three important goals to achieve effectiveness; they are: (i) a process, not product perspective, (ii) cross-functional co-ordination or integration, and (iii) consistency between goals and improvement plans (Wickens, 1995). IT is an enabler to the re-engineered process, and any reengineering program must take account of the tremendous advantage offered by technologies such as document image processing and expert systems (Childe et al., 1994). This indicates that IT can be used to model and analyze business processes and then in reengineering those processes.

The implementation of BPR for a radical change in manufacturing strategy requires the attitude to change and the serious involvement of dedicated individuals and teams (Roby, 1995). Smith (1995) indicates that the major aspect of BPR is the human element. Therefore, companies should ensure that their employees are motivated suitably and the technology required for training is available, especially for radical change with BPR.

The concepts of time-based competition (TBC) and lean production (LP) are of considerable significance of BPR. TBC is process based and aims to reduce radically the time required for an entire process. The corresponding benefits may include increased productivity, price competitiveness, reduced risks and increased market share. In the 1980s, total quality management (TQM) helped incremental process improvements in manufacturing/service organizations, but in 1990s BPR using modern IT. This implies the role of IT and BPR in improving the effectiveness of organizations.

Jones (1995) explains how benchmarking helps to identify and eliminate non-value added work. Benchmarking is one popular technique a plant can use to compare its performance with other plants in similar industries. Combining benchmarking and reengineering ensures that the best practices are in use, and help a firm seek out and eliminate steps that waste resources. This paper focuses on functional integration from process perspectives. BPR requires major organizational and cultural changes to reengineer their business processes through radical change to achieve a dramatic improvement. For such a change effort, the information system has to be restructured to support the reengineering of business processes. The restructuring of information system should support functional integration with an objective to improve the management of supply chain and hence an improved productivity and quality. In the following section, some of the advanced IT are briefed before studying the application of them in BPR.

3. Advanced information technologies

Advances in information technology have radically changed the requirements of distributed systems. The advances of technology in the personal computer have redefined the office environment and created a growing need for open, standard-based, structured cabling schemes designed to handle traffic generated by the networks, independent of where they are placed. This helps to reduce overhead by allowing some employees to work from home or at remote locations where costs are low. Moreover, advances in

IT and the convergence of communication, information, and entertainment industries and helping small businesses with electronics commerce, tradepoint centre and advertising. Further advances in wireless (radio) communication devices will enable off-site employees to interact with inventory, price, financial, and other business data. Manufacturing companies will gain production and sales opportunities more than the current Internet production and marketing once the companies are equipped with Multimedia communication systems, to send and receive audio, video and data. Multimedia have enabled cross-functional decision making in a way similar to that by which the related technologies of voice mail, electronic mail, software-facilitated meeting processes, and video conferencing have enabled and improved communication.

Some of the most useful technologies that are widely being used, for example Multimedia, Internet, www, CAD/CAM, etc. as they are powerful in integrating the various functional areas in BPR. The reasons for the use of IT as a main source of reengineering tools is to restructure the organization and facilitate a cultural change with an objective to reduce the barriers between various functional areas of manufacturing. The IT helps to improve the communication between various functional areas about company goals and objectives that would lead to a co-operative supported work for an improved productivity and quality. Also, IT can be used to integrate both hardware and software elements in an organization that aim to reduce the lead time at various places in manufacturing organizations.

The manufacturing sector has gained productivity through investment in factory automation and IT. Automating the existing processes with IT may lead to more efficient way to do wrong things (Hammer and Champy, 1993). Therefore, it is important that the operations should be standardized and simplified before automation and implementation of IT to improve productivity and quality. However, IT can be utilized in the process of planning the reengineering of various business processes such as 'process mapping' and 'identifying non-value added activities', using the simulation modelling and analysis. In the following section, an attempt has been made to study the role of IT in BPR with a reference to manufacturing.

4. Information technology in BPR

BPR and IT form an integral system in improving the performance of manufacturing companies drastically. Basically, IT can save time and improve accuracy in exchanging information about company goals and strategies. It removes much of the human error inherent complex and repetitive tasks. IT saves money because it reduces errors, and the time it takes to accomplish tasks. IT provides a competitive advantage by helping a company's position and capitalize on trends so that it should be the first to market a new product.

Electronic Data Interchange (EDI) is usually defined as the computer-to-computer exchange of relevant business data and is a set of agreed upon standards that make transfer possible – it is not a common channel. Typical information exchanged might initially be orders and invoices to suppliers. Additional software advances may help to send order acknowledgements, order notices or electronic funds transfer (EFT). In this form, IT is simply automating an existing process. Therefore, EDI should be looked upon as an opportunity to change/eliminate intermediate processes. The objective of simplification and integration before automating has been forgotten all too frequently. While EDI used to be expensive and complex, recent advances in packaged software, bar coding, and telecommunications technology have made EDI affordable to businesses of all sizes. EDI and electronic funds transfer (EFT) enable a retailer to electronically conduct such functions as issuing purchase orders, paying invoices, and processing credit checks. More importantly, EDI is the cornerstone of an effective and continuous replenishment/quick response program, which electronically ties vendors to a retailer's sales and inventory data to ensure that replenishment is co-ordinated as closely as possible with sales rates (Parker and McKinney, 1993). EDI eliminates the barriers between functional areas and within each functional area for a smooth and reliable information flow along various functional areas. In addition, all non-value adding activities are eliminated by avoiding congestion in different functional areas through EDI.

In companies, internal communication is as important as outside communication. For example, networking the computers in a company and installing

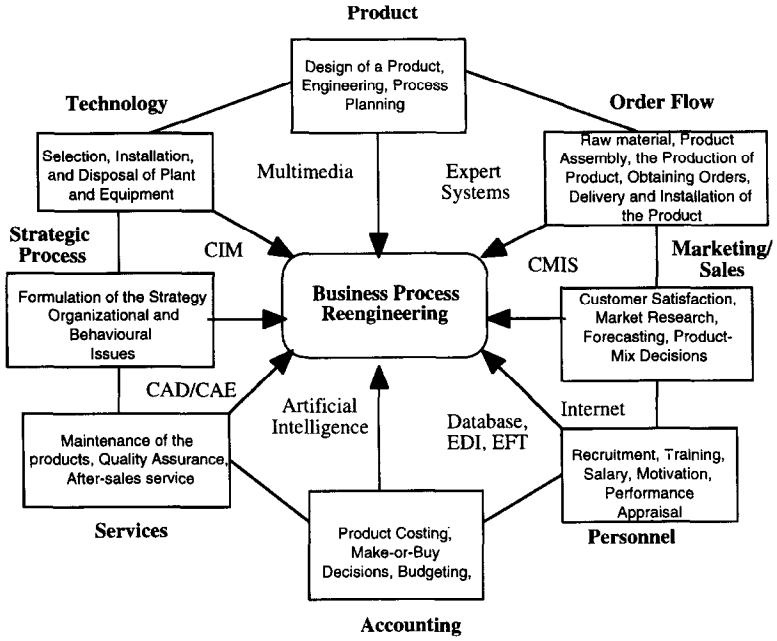

Fig. 2. A conceptual model to illustrate the role of IT in BPR.

electronic-mail system allows employees to send and receive messages among themselves. Also, programs such as NetScape and World Wide Web (www) facilitate access to other business sites for the retrieval of useful data. Such information help companies to compete successfully in a global economy and bring new products to market by making major capital decisions based on more accurate and reliable information. Therefore, advances in IT and the need for making important investment and operational decisions require to link computer-based tools with various business processes.

For the success of BPR in manufacturing/service industries, IT helps to increase the competition base through easy access to global suppliers on databases. Effective integration of various functional areas requires speeding up information flow in a business environment. The lead time for information flow has come down drastically through the use of advanced IT such as E-mail and Fax. The availability of cheap computing power and customizable software, working in rapidly shrinking number of international or industry focused data formats means the pace of EDI implementation is increasing (Panizzolo, 1993). In the last decade, MRP II evolved from primarily a materials requirements planning system into something more fully integrated with both plant-floor operations and the larger concerns of the enterprise – including the customer. The encompassing network of manufacturing software systems has led enterprise to multiple systems, as well as systems for logistics and supply-chain management (Parker, 1994). A conceptual model is presented in Fig. 2 to illustrate the role of IT in BPR. As noted earlier, the process has been defined from different perspectives depending upon the characteristics of the business and strategic goals of the company. Nevertheless, the definition of process in a company has a tremendous significance in influencing the system performance and subsequent activities related to reengineering. The process definition used here is broad in context including the delivery of goods to customers, development of a product, purchasing, recruitment, strategy formulation, technology development and installation. The details of the model are discussed in the following paragraphs.

The conceptual model shown in Fig. 2 illustrates the role of IT in BPR and the major processes involved. These major processes have been identified

based on the critical areas of manufacturing/service industries. The recent literature on improving productivity and quality indicates that there is a need to integrate various functional areas with the help of suitable IT. From the model, it can be easily noted that product, order flow, technology, delivery of goods to customers, marketing/sales, strategic processes, service processes, support services, accounting, personnel, form the part of major business processes. For example, treating the product development as a design process requires the design of a product, engineering and process planning. Reengineering the product development requires to analyze the issues of strategic process, personnel, accounting, services and technology to achieve a dramatic improvement through a radical change, say treating the business process as a project. The details of each of the major business processes and their role in BPR are discussed hereunder.

4.1. Order flow

Defining the process to reflect a drastic change in manufacturing operations will be very difficult to generalize as they should be tailored to the organizational and production characteristics. For example, some companies may have product development as a part of business strategy. In that case, the major process for the company will be the new product development. However, new product development in that case should take into account the principles of design for engineering, design for manufacturing, design for distribution and handling, etc. Depending upon the organizational characteristics, either vertical, horizontal or hybrid, the information flow and hence the corresponding information system should be designed.

Two companies may have the same business situation. However, each company should reengineer its business process based on the process and not based on the function and it should be tailored to the characteristics (organizational structure, skills available, capital available, products, production facilities, etc.) of the company under consideration. Suppose an automobile manufacturing company has received an order from a customer for a specific automobile. If the company's objective is to quickly meet customer demand, then the company needs to analyze the flow of information and materials along the supply chain. The simplification and standardization of the flow of materials and hence the flow of information may facilitate reengineering to improve the overall system performance of the system. The congestion at every point in the supply chain should be identified before formulating information strategy. Information systems such as CAD/CAE/CAM, EDI, EFT and Multimedia can be used to reduce the lead-time of order flows.

Treating the delivery process as a project requires the removal of barriers with information and material flows through the use of advanced IT such as multimedia, shared databases, and process team consists of people from different functional areas, AI and Expert Systems and CIM. These technologies can improve the computer-supported co-operative work in the factory and thus the effectiveness of the system.

4.2. Strategic process

The external factors influencing the supply chain such as government policies, environmental aspects, inflation, general economic condition in the country, competing markets should dictate the choice of strategy. Therefore, there is a need to give importance to these externalities of the network in formulating business strategies in manufacturing. All these externalities will act as constraints or present opportunities for the manufacturing system. The company should turn to a new open IT infrastructure that would link logistics, inventory, and order processing operations with corporate headquarters.

The formulation of strategy requires information about both internal (manufacturing capability, skills available, employee co-operation, management style) and external factors. This implies that there is a need to handle a large volume of data and information processing which would help to formulate suitable business and manufacturing strategies for achieving corporate goals. IT such as video conferencing, Netscape, Multimedia, Internet communication, database, AI and Expert systems can be used to collect and process data. A separate module can be incorporated in the computer-system to access information and exchange relevant information related to strategy formulation by people in various functional areas of manufacturing together with an executive information system. Obviously, the accuracy of the decision depends upon the accuracy of the data collection about both internal and external factors and

easy information exchange among people who are the key players in the strategy formulation.

4.3. Product

Overall, companies that have undertaken successful reengineering efforts have gained dramatic improvements in productivity and cost savings. The key is the use of powerful, low-cost IT to link computer-based tools. Product design and engineering, and process planning can be treated as a business process. Product itself is an object that requires various aspects such as design of a product, engineering, and process planning. These stages can be integrated using the concept QFD, CE, CAD/CAE and CAPP. The ideas of concurrent engineering need to be employed in product development with an objective to reduce the lead time for design and production by eliminating non-value added activities at different stages of the product life cycle. Advances in automation and IT during the last decade have been especially striking in programmable controller-based supervisory control, execution systems, and computer-aided design. These technologies share a dependence on even more basic engineering advances in microprocessors and personal computers.

4.4. Marketing/Sales

Marketing and sales are two of the most information intensive functions in business (Powell, 1994). Marketing research in particular will be a prime benefactor of IT innovations. Even now, CD-ROM libraries are being introduced that carry the full image of articles. Primary data collection is being transformed by IT. Computer-assisted telephone interviewing (CATI) has become more prevalent. Changes now under way include a program to provide the sales force with modem-equipped laptop computers to transmit customer orders right to the order-entry department. The information will not have to be rekeyed after it is received from a salesperson. Instead, it is simply downloaded for use by the product-flow teams that run the simplified, streamlined and reconfigured manufacturing lines. Examples of EDI application include the issues of purchase orders, receiving invoices and payment of suppliers. Marketing/Sales as a process requires to integrate activities such as market research, forecasting and feedback with the objective of providing necessary information to the management of the company in order to satisfy the customers with required quality products and services. This could be achieved by a smooth flow of information between customers and the marketing department, and then to manufacturing. Information communication such as Multimedia and Internet systems can be used to exchange and collect information from customers and within the company as a whole.

4.5. Services

It is an important elements of value adding areas in any organization that has distribution as the business process. A growing number of companies are deciding to contract out the transportation function, thereby cutting costs and improving customer service. Specific aspects involving strategic relationships between companies and carriers need to be analyzed. While these specific aspects are yielding significant cost savings, they are part of a much broader reengineering trend that involves every stage of the supply chain and requires companies to redefine the process by which products are made available, delivered, and paid for. Aspects that are to be considered in strategic alliance with distribution carriers include improving the utilization of equipment, and eliminate unnecessary paper work (through long-term relationships, computer-control information system).

Information automation systems are available for distribution and logistics operations, which often grow cumbersome and ineffective at the expense of cost and customer service. They include logistics-dependent companies from process and discrete manufacturing, retail, apparel distribution and public warehousing. Client/server technologies can be used to share information company-wide; and managers can see the total system instead of individual functions such as marketing or distribution. Client/server is a computational architecture that involves client processes requesting service from server processes. The main advantage of an open client/server system is the flexibility about the hardware and software used. A typical client/server technology has three level architecture: presentation layer, business logic and data layer. The effectiveness of client/server open systems enables downsizing and information automation in all aspects of a company's operation.

4.6. Accounting

The accounting process includes product costing, make-or-buy decision, capital investment decisions, budgeting and product-mix decisions. Computerised information systems including on-line cost information collection and databases help to collect information about various costs of the product at different stages of operations. The accounting system should be tailored to the production process and the company. With the development of activity-based costing and management, companies are implementing more and more non-financial performance measures. The improvement of productivity, flexibility and innovation should be incorporated into the accounting performance measures in order to heap long-term benefits. In addition, capital investment decisions should not consider only financial benefits, but should also include non-financial performance measures such as flexibility and productivity. This area can use the on-line shared database and computerized information system for collecting and processing information about product price, make-or-buy decisions, capital investment and budgeting decisions including product-mix decisions.

Global financial markets and advances in IT have contributed to a revolution in the field of investment management. The expert system for technical analysis (ESTA), and an expert system that performs money management capabilities, help to improve the overall system performance. In addition, the possibility of supplementing ESTA using Artificial Intelligence (AI) and neural networks will stimulate some of the less structured expert's decisions. AI models can be used to provide various benefits to users, including expanded computer efficiency, increased utility, quality, flexibility and reliability.

4.7. Personnel

When the process of manufacturing is being reengineered, what is really happening is the revamping of the way people think and interact with one another. Stillwagon and Burns (1993) described the advantages of the application of human performance engineering to problems of employee, manager, and organizational development. They have introduced a new method called Human Performance Engineering (HPE) – of organizing, developing, and challenging the human resources of an organization, utilizing geometric or algebraic principles as typically found in engineering analysis together with functional elements of performance. A mechanical and economic visualization of the relationship within a particular organization, reflecting human resources change and the corresponding result, the problems related to human resources from top management to the production floor, and a new way of defining jobs, establishing accountabilities, training, and organizational development using the practical concepts of HPE would help to improve the human factors in BPR.

Employees expect their organizations to take a more active role in addressing the stress they face in managing their work life with their home life, especially in BPR (Stillwagon and Burns, 1993). Six recommendations were made: provide greater work time flexibility, provide greater work location flexibility, take an educational role, make a commitment to promote women, re-examine benefit packages, and educate managers. Technologies such as Multimedia, CAD/CAM and Internet can be utilized to improve the co-operation of employees with business and manufacturing strategies and to reduce the stress of workers in performing various operations in BPR, by open and more reliable communication systems.

5. A framework for the design of BPR systems

The successful organizational development for BPR should include: (a) a holistic view of the organization, (b) an endeavour to accomplish simultaneous changes and improvements on several critical variables such as: cost, quality and lead times; customer and vendor relations; utilization of technology; organizational arrangements; and employee learning and competence development, (c) a dynamic and long-term perspective on the change processes, and (d) a development of the work itself and the work related tasks in terms of influence over change and development processes. The following four recommendations can help promote a better understanding of business and will increase the chances for BPR success; immediately assemble a cross-functional team, conduct brainstorming sessions early on to define critical problem

areas, create a high level current business process map, and formulate a vision statement that represents the team's thinking (Cresto et al., 1995). The following six steps can be followed in the development of BPR systems. The BPR system should enable firms to:

(i) Define business processes and their internal or external customers.
First, major business process improvements and technology investments should be established and sequenced. Justification and approvals for such process improvements and technology investments need to be established.

(ii) Model and analyze the processes that support these products and services.
Decide about the specific changes to be made in organization, work methods, job design, processes and supporting information systems. This might include detailed procedures, systems specifications, and organization designs. IT such as computer simulation models, Multimedia, object-oriented technology, workflow models can be used to model and analyze the processes that support products and services.

(iii) Identify opportunities for both radical and incremental business improvements through the identification of non-value added activities and removal of any waste and inefficiency. Software available for activity-based analysis can be used to identify non-value added activities.

(iv) Implement improvements through a combination of IT and good working practices. Information technologies that include EDI, MRPII, Multimedia, CAD/CAM can be utilized to improve the working practices. In addition, these include other equipments, customer relations, supplier relations, etc.
In this stage, make preparation for change, develop necessary systems, and install the reengineered processes and systems. It includes development, testing, detailed implementation planning and control (Hales and Savoie, 1994). Computer simulation models can be used to evaluate the performance of the reengineering business processes.

(v) Establish a monitoring system to ensure continuous improvement of the redesigned processes. Computerized models such as CAN-Q models and on-line performance measuring tools can be used to evaluate the performance of redesigned business processes.

(vi) Analyze the importance of top management, leadership, training, and reward systems and their role in BPR. Certainly IT has the potential to impact these important areas. IT such as Multimedia, Strategic Information Systems, and simulation models can be used to motivate the top management in BPR.

The following problems of BPR can be overcome by IT as shown in Table 1: (i) fixing the process instead of changing it, (ii) loss of nerve, (iii) the barons, (iv) change of company champion, (v) settle for minor results, (vi) culture, attitudes and skill base, (vii) skimp on resources, and (viii) pull back when people resist change. For example, fixing the process instead of changing it requires explaining the importance of BPR through computer simulation and workflow models. This will motivate the people in a company to go for reengineering the business process for a dramatic improvement in the performance. However, lack of resources will pull back from the idea of BPR. Therefore, top management should be motivated that BPR requires a radical change in the way the operations are managed. The length of the manufacturing cycle time can be reduced by reengineering the process using CAD/CAM and CIM. Nevertheless, it is a tendency that the company may try to cancel the BPR program when the people resist. The resistance can be overcome by explaining the potential of reengineering using Multimedia, EDI and Simulation and to achieve a computer-supported co-operative work.

According to Stoddard et al. (1996), reengineering design may be radical, but implementation is incremental. Reengineering design is top-down directed, but implementation requires acceptance from the bottom-up. Reengineering design is enabled by IT, but the implementation might be initiated without much of the assumed IT capability. Bradley et al. (1995) presented different software tools available for BPR. To support BPR efforts, van der Aalst and van Hee (1996) proposed a framework based on high-level Petri nets. Business process redesign focuses on the fundamental rethinking of business processes, ignoring organizational boundaries. However, before implementation of new business processes, the existing system with the new situation should be

Table 1
Problems in BPR and the role of IT in solving them

Problems	Information technologies
Fixing the process instead of changing it	Reengineering by 'process mapping' and 'simulation' with help of computer softwares
Loss of nerve	Training and education through 'Multimedia system' for a team work
The barons	Executive information system with multimedia capabilities
Change of company champion	Aware of the potential of IT and equip with such IT that would facilitate BPR
Settle for minor results	Benchmarking through information collection using computer databases, EDI
Culture, attitudes and skill base	Multimedia education and training systems
Skimp on resources	Reengineering the information system using CIM, CAD/CAM and EFT for radical change
Pull back when people resist change	Computer-supported co-operative work using multimedia

compared. It necessitates a tool with the help of IT to quickly capture and model existing processes as well as new processes. Several other techniques have been proposed to support BPR efforts. Diagramming techniques such as flowcharts, decision trees, Warnier–Orr diagrams, state transition diagrams, hierarchy charts, dataflow diagrams and business activity maps (Morris and Brandon, 1993; Emrich, 1993) have been used to represent business processes. High-level Petri nets are easy to understand and have formal semantics.

6. List of suggestions for BPR

The application of IT in integrating various functional areas to reengineer business process is presented in Table 2. In reengineering the business process, the IT plays a major role to integrate various functional areas for reducing the cycle time for the delivery process of the goods/services. BPR requires eliminating barriers within each functional area and between various functional areas for a smooth flow of information and hence progress of business service processes to achieve a reduction the cycle time of business processes. For example, marketing requires a strong link with customers and other functional areas of manufacturing to facilitate smooth, timely and reliable information flow to eliminate any sort of congestion in the supply chains (Evans et al., 1993). This could be supported by multimedia, Internet and Database to explain the product features and to receive orders and deliver the products. The database can be common between marketing, production, purchasing and accounting. Similarly, CAD, CAE and CE, database, EDI and EFT can be used to link design and engineering with other functional areas such as marketing, production and accounting. It is indeed very important to develop an information system that links appropriate functional areas. IT such as Internet, on-line inventory and shipment controls, database, barcoding DRP, Satellite positioning, EDI can be used to eliminate any sort of congestion or non-value adding activities and to link with information systems in other functional areas, such as design and engineering, purchasing and accounting. Evidently the role of functional integration from the perspective of treating the business as a project and managing the project most effectively is important. Nevertheless, an information system incorporating various IT will act as a manager for the business processes (projects) to eliminate any sort of congestion or non-value adding activities, and to achieve a dramatic improvement in overall performance of the company. In specific, the suggestions include:

(i) More traditional techniques such as cause-and-effect analysis, Ishikawa diagrams, Pareto analysis, and process flow charting proved to be useful support tools for the process reengineering activities. These should be supplemented by a powerful time-based analytical tool. This analytical tool should use the appropriate criterion and categorize every process step as either useful or redundant. It proved invaluable in identifying process improvement opportunities. Having identified redundant steps for elimination and opportunities for overlapping the remaining necessary process steps to develop the supply chain construct, verify the practicality of the proposed process

Table 2
Information technologies in the integration of functional areas from process perspectives

Functional areas	Information technologies
Marketing	Multimedia, internet, database
Maintenance	AI and expert systems, computerized maintenance, scheduling, database
Distribution	Internet, on-line inventory and shipment controls, database, barcoding, DRP, satellite positioning, EDI and customs clearance
Personnel	Computer-supported co-operative work, multimedia training, database
Accounting	Computerized data collection, shared database, spread sheet
Design and Engineering	CAD, CAE and CE, database, EDI and EFT
Purchasing	Internet, database, MRP II, database
Production	CAM, CIM, multimedia, MRP II, database, scheduling, online data collection, barcoding and EDI, SPC systems

changes and select the scale of the cycle time reduction opportunities by using appropriate knowledge-based systems modelling techniques.

(ii) The product manufacturing practice for BPR can include enterprise, integration, shared databases, multimedia information networks, product and process modelling, intelligent process control, virtual factory, design automation, supercomputing, product data standards, paperless transactions through electronic information interchange and the high-speed information highway.

(iii) Successful utilization of IT requires cultural and organizational change. Business process reengineering, which involves the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures, or performance, is one solution. Successful competition in the global environment of the 1990s will require the use of both business reengineering and IT. The information technology provides an opportunity to simplify the business processes and hence the information flow. Manufacturing concepts and technologies such as JIT and GT cells can be used to streamline the information and hence the material flows. This requires integrating functional areas of manufacturing for open communication and leading to a cooperative supported work.

(iv) Companies should start from top-down for reengineering the business process. Reengineering should be distinguished from other business programs. Once a business program has been identified as a re-engineering candidate, BPR should not just correct it, rather it should strive for quantum leaps.

(v) Companies can start by identifying first the business process which forms the critical factor of the productivity and quality. Secondly, suitable IT should be identified that can improve the reengineering program. The information strategy and business process strategy should promote the competitiveness of the firms. Shared databases can help to reduce the information lead time. In BPR, utilization of expert systems which use decision-support tools (database access, modelling software), will improve the decision making and reduce the lead time of the over all business process in a company (Steinberger, 1994). Simplification of material flow through reengineering helps not only efficiently implement the information technology, but also facilitates the continuous improvements in the system performance.

(vi) To obtain windows into actual inventory levels, order demand, and shipping and invoicing activity, a company should install a network of PCs and minicomputers. The software supporting the interactive processing needs to be user-friendly, a graphic user interface that depicted information with colour icons and graphics allows users to visually assimilate data rapidly without the tedium of scanning character-based, monochrome text. EDI reduces the cost of processing paperwork at both ends. Customers

are allowed a direct EDI linkage to a customers' database. This linkage enables customers to monitor activities in real time. Electronic Commerce on the internet globalize the business and introduces competition and efficiency.

There is a need to analyze the management issues of BPR after reengineering. The team work in BPR should be improved by suitable incentive schemes and continuous training. Computer simulation modelling and analysis can be used to identify the areas of process improvements.

7. Concluding remarks

In this paper, a conceptual model and strategic framework are presented for BPR. The issues of BPR have been discussed as well as the application of IT in BPR. Many companies address BPR through IT such as document image processing and expert systems. The authors believe that there is a substantial commonality of processes across industry types. The strategic capability may vary. For example, engineer-to-order companies will have strengths in the product development process, make-to-stock companies will have to focus attention on the whole logistics supply chain. This should involve using manufacturing flexibility and IT to make the end product highly customized for the end user. Also, service industries need to use IT in their BPR for improving productivity and quality. The following are EDI benefits: (i) reduced handling costs, (ii) reduced and consistent order cycle lead times, (iii) reduction in stock, (iv) reduced risk of lost orders, (v) security, and (vi) close relationship with suppliers and customers. The global view of the pipeline contains complex flows of goods and information through multiple production and distribution channels. To control these flows and provide an efficient logistics system, the flow of goods must be backed up with an accurate and timely information system.

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