Re-engineering Business Processes to Facilitate Data Mining

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Abstract

Business process re-engineering and data mining are currently popular discussion topics in business and industrial environments. One main area for discussion is how organisations can be prepared to facilitate data mining technologies appropriately. Based on the two main phases on business process re-engineering, the data mining process, and the involved expertise respectively, a synthesis of both disciplines, based on the data warehousing philosophy, is proposed. Furthermore, requirements are given — general as well as industry specific — which an enterprise has to provide to allow appropriate data mining, including domain independent real world scenarios.

1. Introduction

During the last five decades, a variety of improvement philosophies have been proposed by the research community to revitalise, simplify and optimise business units and processes. Examples are Just-In-Time production, Total Quality Management, Simultaneous Engineering and Time Compression Management ([Pep95]). The most recent promising method is Business Process Re-engineering (BPR), which concentrates on the installation of flexible, simplified processes that operate at the inter-functional, intra-functional and inter-organisational levels. It has also been stated that knowledge based systems support and influence the application of BPR to individual companies ([Mul96]).

Data Mining also known as knowledge discovery[1], is one of the encouraging knowledge based technologies which combines database functionality and machine learning methods for the "non-trivial process of identifying valid, novel, potentially useful and ultimately understandable patterns in data" ([Fay96]). To allow proper knowledge discovery from databases, traditional business organisations are inappropriate, and thus, are a potential candidate for change.

The objective of this paper is to describe how BPR can be used by organisations in order to prepare them for the application of data mining techniques. The status quo of current business process re-engineering research as well as the two phases of BPR is described. Section 3 describes briefly the usual steps of a state-of-the-art data mining process. In Section 4 the two interrelated disciplines are merged and the conglomerate is embodied in the concept of data warehouses. A list of requirements is proposed, general as well as industry specific, which an enterprise has to provide to allow appropriate data mining, including hypothetical real world scenarios.

[1] This notation does not conform with the terminology proposed by [Klo96], but mirrors the common usage in industrial environments.

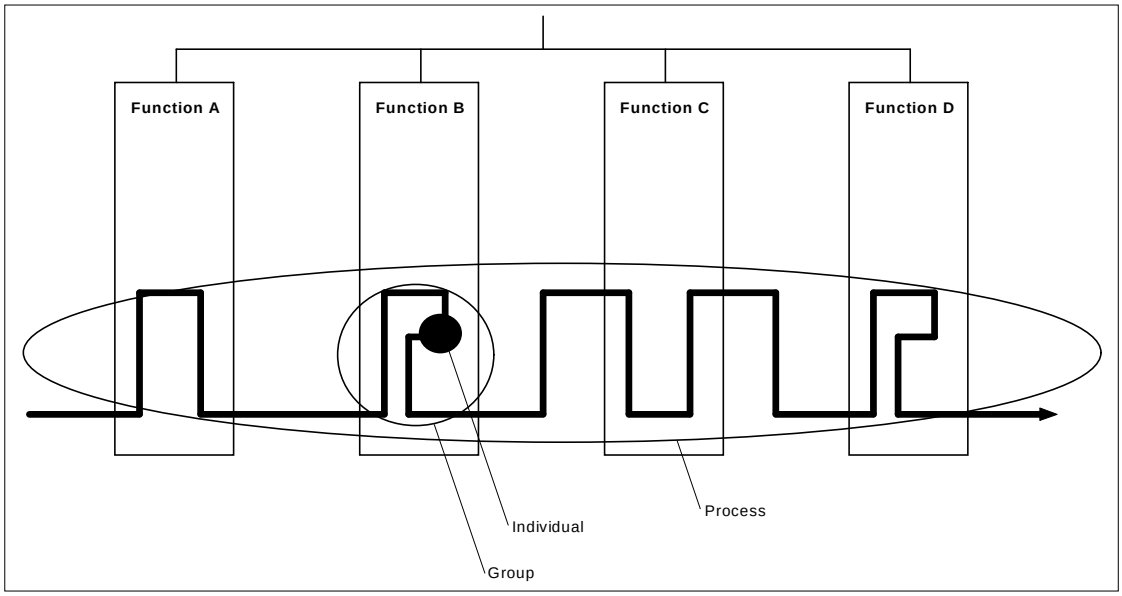

Figure 1: Processes and Process Initiatives in a Functional Organisation

Finally, conclusions are drawn and further work is outlined.

2. Business Process Re-engineering

BPR is a methodology that enables an organisation to make fundamental changes in the way it carries out its business. In BPR, the focus moves from function to process (Figure 1) where, for example, traditional functions such as sales may be overhauled, simplified and reconstituted as processes ([Chi94]).

What are the goals of this re-engineering effort? Certainly, within an organisation, the main goals can be described as: flexible and simplified processes; empowered employees working in a team environment; removal of non-value-added tasks; and ultimately more financial controls and lower operating costs to the organisation. But the most successful adopters of BPR see these goals as secondary to the primary goals that fuel an organisation's competitiveness and ability to operate successfully in increasingly difficult market arenas. These goals include: the adherence to quality standards; the managing of suppliers; and most importantly, the responsiveness to customers. The rewards of BPR can be across-the-board improvements in value, quality, customer support, and productivity; which are achieved by the new business processes possessing inherent flexibility, agility and responsiveness.

2.1. 1st and 2nd Order BPR

Supporters of BPR advocate that the re-engineering of a company's important business processes should be a revolutionary event ([Ham90]), and not evolutionary or revelationary. However, recent work on practical application of BPR ([Cha96]) suggests that an evolutionary approach, more recently called *morphostatic* BPR ([Bur95]), may be more acceptable to management and staff than the revolutionary, or *morphogenic*, approach. The morphostatic approach may act to prepare an organisation for the more rigorous application of morphogenic BPR. For this reason, morphostatic BPR is sometimes termed *first order* BPR, while morphogenic BPR is termed *second order* BPR. In practice, companies have used 1st

order BPR to experiment in the use of the method, and are now ready to instigate measures in their organisations to develop BPR as a 2nd order mechanism.

2.2. The Role of IT in BPR

BPR is commonly facilitated through the application of appropriate Information Technology (IT). Historically, IT has enabled business processes within functional areas of companies such as manufacturing. However, this application of IT makes the *a priori* assumptions that companies are optimally organised already, and that the functional approach can manage change elegantly. As a result, adding IT to the existing functionally-based processes can guarantee only to computerise non-optimal processes that will be difficult to change. The equation which states that 'new technology + existing business practice = new expensive business practice' is very appropriate in this situation.

In new, lean business processes where non-value added tasks have been removed, IT can enable manufacturing philosophies, e.g., Optimised Production Technology or Just-In-Time (JIT). However, complex problem areas will still exist in reengineered companies. These problems will occur with large and small companies, and basic IT cannot address them. They include the handling of incomplete, conflicting and vague data, the discovery of knowledge in massive data sets, the interpretation of legislation and inter-organisational contracts, the management of change, and the reapplication of an expert's accrued experience and expertise. KBS techniques provide a series of tools that can help to assess, manage and ameliorate these problems ([Aik93], [Har93]). Knowledge engineering, which is the name given to the process of building KBS, applies specialised techniques to acquire, represent and use

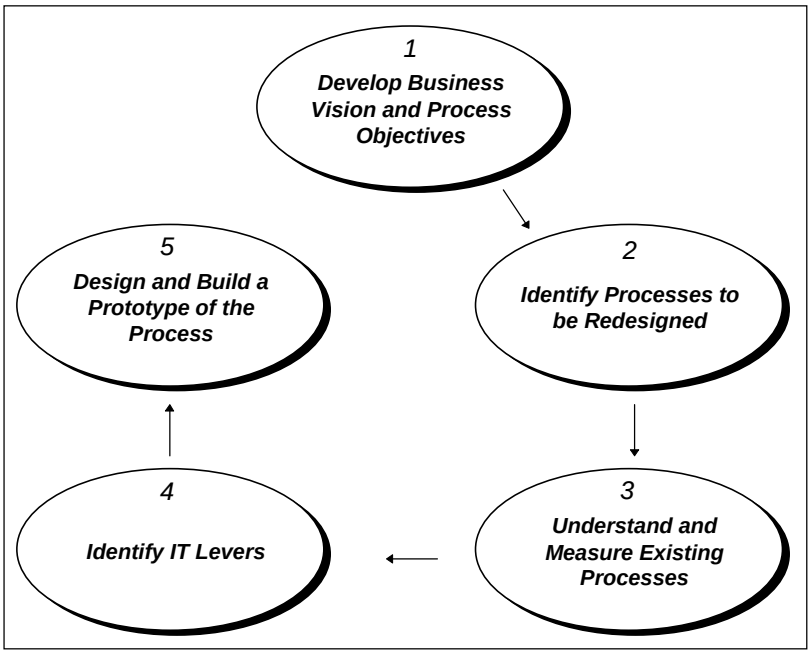

Figure 2: Five Steps in BPR

business process knowledge. There have been a number of reported successes where KBS have added value to business processes ([Cod92], [Att95]), and in fact made their re-engineering possible in the first place.

2.3. Initiating BPR in an Organisation

Davenport ([Dav90]) has identified the five major steps to be addressed in 1st or 2nd order BPR. These are to: develop business vision and process objectives; identify processes to be redesigned; understand and measure existing processes; identify IT levers; and design and build a prototype of the process (Figure 2).

The vision and objectives in the first of these steps is the balancing of factors such as cost and time reduction, quality of output of process, improvements in worklife, and the empowerment of employees through process

buy-in. In the second step there are alternate strategies that may be used. The most popular of these is to focus on those processes that can have the highest impact on an organisation. Another option is to use techniques that identify those processes that may be most data-rich, and can perhaps benefit from the application of IT-enabled BPR. Measurement of process is the third vital step. If there is no way to gauge how a new re-engineered process has impacted an organisation, either financially or in other more indirect ways, then it may be difficult to champion the changes that BPR may bring. The fourth step can, if directed correctly, lead to massive improvements in how a company carries out its business. IT is central to the success of a great majority of BPR operations, and with technologies such as the Intranet, data warehousing and knowledge based systems available, quantum leaps can be made in addressing major corporate problem areas. The fifth step is important because it provides the organisation with the visible results of a BPR exercise. It also enables the BPR team to develop a more generic model for further BPR application.

Table 1 gives illustrative examples of 1st and 2nd order BPR across the process dimensions of entities, objects and activities. These dimensions enable appraisal of BPR in any commercial or organisational sector.

2.4. The BPR Teams

It is crucial that the participants in any BPR activity understand their roles, and their interactions with colleagues. The most important participant groupings in a BPR exercise are: steering committee; design teams; implementation teams. In addition, key personalities are the project sponsor, and champion.

The steering committee should provide insight and guidance to the overall project, and should comprise staff from the business units or areas affected by the re-engineering work. The design teams are comprised of operations managers who will spend at least

Process Dimension and Type	Typical Example	1st Order BPR	2nd Order BPR
Entities:			
Inter-organisational	*Order from supplier*	Remove non-value-added tasks	Re-engineer entire supply chain process
Inter-functional	*New product development*	Streamline costs	Remove department barriers and form cross-functional product design team
Inter-personal	*Approve bank loan*	Introduce more systematic, consistent approach	Overhaul thinking behind loan approval process and rethink strategic goals
Objects:			
Physical	*Product manufacture*	Introduce TQM measures	Introduce fault tracking process: design-to-build
Informational	*Proposal development*	Focus on key decision-makers	New process using decision-support systems to ensure consistency, accuracy and quality
Activities:			
Operational	*Generate customer quote*	Change to business units built around streamlined processes	Introduce external customer leverage. Make quoting process explicit and open to customers
Managerial	*Develop budget*	Form Budget Development Business unit to bring key people together	Empower business units by making them responsible for costs and profits

Table 1: Types of Business Processes (adapted from [Dav90])

50% of their time on the project, while the implementation team members will have a responsibility on the detail of the re-engineering work, and will typically work closely with the design team.

The project sponsor must be capable of envisaging how the re-engineering project will address the strategic problems relating to the business, and will be capable of channelling funds and other resources to the various BPR teams. The champion is the BPR expert who works closely with all teams, especially the design team where he/she must co-ordinate the overall design effort. The champion reports frequently to the project sponsor and is fully committed to ensuring the success of the project.

3. The Data Mining Process

There have been several suggestions for describing a domain independent data mining process, e.g. [Ana96], [Bra96], or [Fay96]. We use [Ana96]'s proposal, because in addition to the process itself, it also considers the roles of involved experts, which is essential when facilitating data mining in a re-engineered business (Figure 3). In the following 2 sub-sections, we describe briefly details of the data mining process itself and human resources which participate in the it.

3.1. Details of the Data Mining Process

After a problem has been identified at management level, *Human Resource Identification* is the first step of the data mining process. Human resources which are required in a typical data mining project are a domain expert, a data expert and the data mining expert. The involvement of each expert at individual stages of the process is described in Section 3.2. *Problem Specification* is the second phase of the data

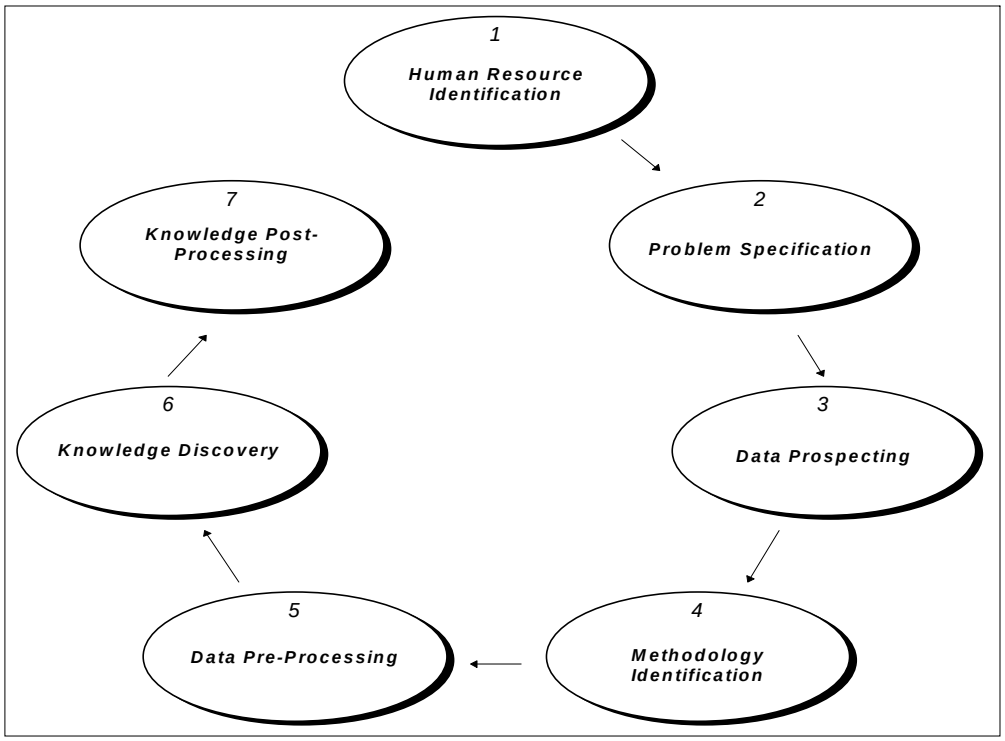

Figure 3: The Data Mining Process

mining process, where a better understanding of the problem is developed. The problem is identified as a particular data mining task, such as discovery of association rules, classification rules, time series behaviour, or characteristic rules, among others. The task allocation is also influenced by the potential user of the discovered knowledge, because some techniques provide a format of knowledge in which readability is inappropriate, e.g. a neural network can be used for a statistics package, whereas it would be useless for a human being. To actually solve the given problem, data has to be analysed. *Data Prospecting* covers locating relevant attributes, making sure that electronically stored data is accessible, and testing the population of the required attributes. The main task of the *Methodology Identification* phase is to find the best knowledge discovery methodology, or combination of such, to solve the specified mining problem. The most commonly used technologies are rule induction, derivatives of traditional statistics, genetic algorithms, evidence theory, case-base reasoning, Bayesian belief networks, fuzzy logic, rough sets and neural networks. The chosen paradigm depends on the type of information that is required and the domain of knowledge being discovered. The next phase is *Data Pre-processing*, which involves removing outliers in the data, predicting and filling-in missing values, noise modelling, data dimensionality reduction, data quantisation, transformation and coding, as well as heterogeneity resolution. The *Knowledge Discovery* phase consists of using algorithms that automatically discover patterns from the pre-processed data. The choice of algorithm depends on the mining task chosen earlier on. The output of the knowledge discovery step is knowledge derived from the searched data. The last step of the data mining process is *Knowledge Post-processing*. Trivial and obsolete information has to be filtered out and discovered knowledge has to be presented in a user-readable way, using either visualisation techniques or natural language like constructs.

3.2. Human Resources

As mentioned above, the main human resources needed during the data mining process are the data expert, the data mining expert, and a domain expert. The *Domain Expert* is in charge of knowledge about the semantics of the data, i.e., the meaning of all attributes, as well as interrelationships among them. They are involved in the problem specification and the knowledge post-processing. The *Data Expert* has to be familiar with the data itself, i.e., administration of the data in a database system, as well as using methodologies to encode information in the data. The data expert is involved in the steps of data prospecting and data pre-processing. The *Data Mining Expert* has to be familiar with knowledge discovery techniques and methodologies to use to achieve results, which solve the given problem. They are involved in most of the stages of the data mining process, namely problem specification, data prospecting, methodology discovery, data pre-processing, knowledge discovery, and knowledge post-processing. It has to be stressed that it is essential to bring the expert human resources together as early as possible in the process. Non co-operation will lead to unsatisfactory results later on in the data mining process.

4. The Data Mining and BPR Synthesis

As has been outlined in the previous two sections, BPR as well as data mining can be formulated as a process of activities. But, to actually fully profit from knowledge discovery techniques and methodologies, an

enterprise has to provide information, i.e., data, appropriately.

About a decade ago, the *OnLine Transaction Processing* (OLTP) had been introduced; a method to run transactions upon data within client-server environments. At this stage, many businesses changed their information technology landscape without changing their corporate philosophy. As a consequence, many tasks have been performed outstandingly, whereas decision-making became more awkward and cumbersome. This phase correlates chronologically and from a contents point of view with the status quo of business organisations. Functions were modelled as entities within a database, and relations among those entities symbolised their interrelationships. Transaction processing mirrored the information flow between functions.

As a solution to that dilemma, *OnLine Analytical Processing* (OLAP) has been introduced, which has been defined by its inventor [Cod93] as the "dynamic synthesis, analysis and consolidation of large volumes of multi-dimensional data". OLAP formed the basis for *data warehouses*, which can be seen as a top layer of existing databases in a company, acting as an important decision-making vehicle. The main functionality of a data warehouse is acquisition of internal as well as external data, building a central repository containing relevant data and business rules, analysis of data, powerful query mechanisms and modern reporting tools. At this stage many enterprises were — and still are — willing to expand their information technology landscape (again), but also to change their corporate philosophy. This phase synchronises well with morphostatic or 1st order BPR, as described earlier.

Due to the fact that data mining is a decision-making support technology, it will be the logical consequence that knowledge discovery techniques will be embedded in data warehouses in the very near future. Implanting data mining in data warehouses will influence all existing components: acquisition of data will be supported with machine learning techniques; central repositories will be extended with expert systems functionality; analysis of data will not be only based on traditional statistics, but also on various uncertainty handling paradigms; query languages have to be expanded linguistically; and report tools have to able to list and visualise not only data, but also discovered knowledge. This can be seen as the ultimate goal from the knowledge discovery point of view. But, to achieve the required results, business processes have to be re-engineered dramatically; a scenario that has been described as morphogenic or 2nd order BPR. The business process arrangement should be organised as closely as possible to the data mining process as described in Section 3.

Both approaches are goal-oriented. In data mining, the goal is to generate meaningful and useful heretofore-unknown knowledge pertaining to a database or databases. The method is to move from OLTP to OLAP incorporated in data warehouses. In BPR, the goal is to create simplified, flexible processes with non-value-added tasks removed. The method is to re-engineer existing functional areas or process domains.

Table 2 develops the examples given by [Dav90] for types of business processes by identifying possible roles for data mining in specific re-engineered process areas.

Process Dimension and Type	Typical Example	Example Data Mining Role
Entities:		
Inter-organisational	*Order from supplier*	Detect trends and perturbations by cross-linking parts and supplier databases
Inter-functional	*New product development*	Use data mining to identify customer clusters where minimal product penetration has occurred
Inter-personal	*Approve bank loan*	Provide closer focus to help identify potential loan customers with lower propensities to lapse on repayments
Objects:		
Physical	*Product manufacture*	Forecast provision of parts supply for more efficient JIT production
Informational	*Bid / Proposal development*	Cross-link and mine past successful / unsuccessful bids with customer files
Activities:		
Operational	*Generate customer quote*	Cross-link quote and order databases and mine for generic rules that identify successful transitions from quotes to orders
Managerial	*Develop budget*	Cross-link business units costs, profits and budget databases to identify generic rules for profitability

Table 2. Examples of Applications of Data Mining (adapted from [Dav90])

The synthesis of data mining and BPR can be viewed at two distinct levels of granularity. This helps to breakdown and simplify the synthesis. Firstly, there is the coarse-grained synthesis, where the data mining process as a whole has the BPR method applied to it. This view generates a series of requirements which impact upon the technical, human resourcing and management areas in an organisation. In order to apply data mining algorithms to a company database, the technical managers must put in place hardware and data access software that has some OLAP capabilities. If the project is to determine the feasibility of data mining, then a segment or extract of the large OLTP database may be placed on a workstation removed from the day-to-day company operations. The resources in terms of skilled IT staff and marketing staff must be brought together into a multi-disciplinary team, with agreement from their managers that a minimum of 50% of their time is available to address the data mining problem. The management have to ensure that the project has visibility at board level and throughout the organisation, and that sufficient resources are made available to the data mining team.

Secondly, the BPR method can be applied within the tasks of the data mining process as identified in Figure 3, although for clarity the distinction between 1st order or 2nd order application of BPR is omitted (see Table 3). The goal for these sub-areas — to which BPR can apply — is to produce simple, flexible and manageable processes with clear delineation of: who is involved; what are the inputs and outputs; and the perceived gains.

Data Mining Process Tasks	*Area of Synthesis with BPR*
Human Resource Identification	Building of inter-disciplinary teams
Problem Specification	Develop top-down process goals; Prioritise work agenda on processes; Identify algorithm / technique applicability to specific processes
Data Prospecting	Develop quality measures; Ensure data access and availability through data warehousing (or data extracts off-line for pilot / feasibility study)
Methodology Identification	Introduce problem-methodology mapping, e.g. using if-then-else scenarios.
Data Pre-processing	Improve data quality through better input validation; Resolve multi-coding and heterogeneity through more homogenous IT landscape
Knowledge Discovery	Incorporate the knowledge discovery step as regular task in the business process to ensure knowledge is up-to-date (aka knowledge maintenance)
Knowledge Post-processing	Develop processes to aid evaluation of knowledge output; Identify process to incorporate discovered knowledge into new corporate business models

Table 3. BPR Synthesis within discrete Data Mining Tasks

5. Enterprise Requirements to allow Data Mining

In this section the requirements of an enterprise to allow data mining is described. A set of general demands that are valid for any company independent of its industrial nature is proposed. Due to the fact that different business branches embody different functionality and processes, two representative branches are used to show the requirements. More key applications such as administration, science or medicine, to which transfer building should be straightforward, are described in [McC96].

5.1. General Requirements

The general BPR requirements can be stated in terms of the success factors for BPR introduction ([Let94]):

- The re-engineering effort must be clearly and directly linked to specific business objectives;
- The organisation must establish a strategy for change that anticipates likely obstacles to effective re-engineering;
- Support structures must be skilled and empowered to undertake significant change;
- The re-engineering effort must be straightforward and practical and feature simple implementation steps;
- Performance is measured and correlated with strategic objectives.

From the viewpoint of data mining, additional enabling technologies have to be provided to set up an appropriate knowledge discovery environment ([McC96]):

- Incorporation of a data warehouse on top of the IT landscape, to profit from the OLAP technology;
- Provide distributed and heterogeneous data access, e.g. using ODBC;
- Usage of parallel hardware and data access technologies to gain better performance, and allow scalability;
- Multi-dimensional servers, which can act as pre-clustering of data, and also improve data access performance;
- Modern reporting tools to verbalise, tabularise or visualise knowledge.

The synthesis of the differing BPR and DM requirements indicate that to be successful, an organisation must take on-board significant resolve for technological change in addition to keeping a clear focus on the business objectives, and must clarify the strategy to achieve those objectives with: key players; employees; customers; and suppliers.

5.2. Financial Organisations

Financial organisations such as banks, insurance companies, building societies, etc.,

are at a crucial period in their development. Customers are increasingly, and rightly, more fickle in their selection of financial advisors. They demand a more personalised service, with flexibility in facilities like direct debiting, mortgaging, etc. The financial organisations have invested millions in large OLTP systems that cannot cope with current customer requirements and cannot easily provide customer information for marketing purposes. In addition, fraud detection becomes a highly interesting topic to protect both customers as well the financial institution.

To tackle both problems, additional marketing and security expertise is required. Enquiries about customer services cannot be based on simple factors, like income, job position, etc., anymore; a redirection through a decision-support system without losing any performance makes organisational changes necessary. Access to historical data, such as transaction times series or customer profiles, might be needed to search for necessary information, which might not conform to existing authorisation policies.

The requirements in financial organisations focus on a need to address the business demands, aspirations and market expectations of customers and clients whilst managing the changeover from legacy systems with their attendant massive investment to systems that are capable of OLAP, data warehousing, parallelism, etc.

5.3. Manufacturing

Manufacturing covers a broad spectrum of industries, each with its own special production methods. However, carrying out the following may constitute BPR in general manufacturing circles:

- Simplification of production flow;
- Introduction of JIT;
- Flexible production and distribution;
- Introduction of concurrent engineering;
- Continuous improvement plan;
- Establishment of ‘Quality circles’.

Data mining may most profitably be used in manufacturing to identify areas where improvement exercises should be directed, such as in: process control; quality control; and maintenance. These three areas are closely inter-related and address directly the solving of traditional business problems by providing the tools to enable efficiency gains, quality gains, better forecasting and planning ability; and improvements in product consistency.

Data mining processes may also impinge on other processes in manufacturing: strategic planning; sales or order winning; financial control; supply chain management processes.

Manufacturing organisations are continually striving to cut the operating costs of their manufacturing processes. The application of DM techniques is therefore best directed in this environment at achieving this goal.

6. Conclusions and Further Work

Organisations in the manufacturing and financial services areas are continually striving to achieve internal and external quality standards, to serve their customers and to ensure supplier compliance. In the current IT environment where legacy OLTP systems are being replaced or complemented by OLAP systems, organisations in all market sectors that rely on databases for market intelligence, forecasting, planning, etc., require a method that enables them to minimise the risk of the introduction of this new technology. BPR provides a method that offers risk management and empowers an organisation to address strategic business goals, and re-

engineer the processes that can realise those goals. Data mining is the next-generation tool that can use the previously under-utilised data resources that most companies hold to enable those companies to gain competitive advantage in increasingly important market areas. This paper has illustrated that the use of data mining, while being a leading-edge technology, can be managed, exploited and maximised by synthesising the technique within the method of BPR.

The described methodology is partly domain independent (data mining process and its participating expertise, as well as general BPR requirements), and partly dependant on a particular industrial sector, as outlined in Sections 5.2 and 5.3. A domain independent methodology, i.e., a framework in which different requirements from different branches can be incorporated, is highly desirable.

We have investigated BPR from a data mining point of view, i.e., how business process should be re-engineered to facilitate data mining appropriately. Further research is necessary to study the feasibility of this approach to facilitate other IT-driven decision-support facilities within the same enterprise.

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