A comparative study of the simulation analysis of e-business implementation in manufacturing companies

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Abstract

The use of collaborative tools in manufacturing enterprises has increased with the introduction of the Internet and other ICT tools. The integration to collaborative environment will have repercussions in the internal business processes of manufacturing companies. Although it is tempting to jump on the e-business bandwagon, the adoption of e-business tools must be analysed not only qualitatively, but also quantitatively.

The paper presents the use of simulation as an evaluation tool for the analysis of e-business effects on the business processes of manufacturing companies. The gap in the literature is presented, as well as the ensuing research questions. Two case studies are used to demonstrate the applicability of the proposed approach and to investigate some of the issues to be taken into account for future research.

Keywords

BPR, Simulation, e-business, e-processes, business processes.

INTRODUCTION

The advent of the Internet and its potential for collaboration between companies has signified that now not only the big multinationals have the opportunity to establish electronic commerce (e-commerce) channels. The whole array of enterprises faces now the dilemma of whether to embrace the new technologies or not in either of their forms (Business to business B2B, Business to Consumer B2C). Furthermore, Porter says "Many companies see the move towards e-business not as question of whether to proceed but when to proceed" (Porter 2001).

For those "brick-and-mortar" companies that want to take that step, guidelines are required for managing the change process and adapt their business processes to cope with the change in demand patterns and responsiveness required.

The present research intends to analyse the necessary changes in the company's business processes in order to be able to react to an e-commerce environment. A simulation approach is proposed as an analysis technique in business process

modelling to evaluate the impact of e-commerce and to select the best re-configuration of current business process to deal with this change effectively and efficiently.

The paper presents the initial results from the ongoing application of the research, focusing on the lessons learnt from two cases studies carried out to test the proposed approach. The paper is divided in the following sections: First, the research need is identified, followed by the theoretical background of the research covering e-business, business process management and business process simulation. Next, the two case studies are presented and described in detail, together with the comparison in approaches. Finally, conclusions are drawn and future steps of the research identified.

RESEARCH NEED

Although electronic commerce is having an impact in the way companies make business, its penetration, as shown in Figure 1, is not equally distributed along the different business sectors.

Figure 1a - E-business Drivers

Figure 1b - Key Issues in e-business

Farish (2001) reports that manufacturing is the sector with the lowest rate (13%) of e-pioneers (i.e. those using Internet technology to support the most crucial activities of the business) and the highest rate (41%) of e-laggards (i.e. those business that have yet to evolve beyond the most basic Internet-enabled applications such as Email). In addition, (Sweet 2001) reports that apart from security (96%), the main concern for companies when developing an e-business strategy is the re-

alignment of business processes (Figure 1b). Paradoxically, Sweet describes in the same report that the simplification/re-engineering of business processes is one of the main drivers for e-business implementation (Figure 1a).

It can be argued that one of the main deterrents of e-business adoption is the uncertainty about how this implementation will affect the business processes (internal and external) and how to manage this change. Accordingly, the Hurwitz Group (2000) say: One of the most difficult, yet ultimately most rewarding, parts of an e-Business transformation centres squarely on the enterprise's ability to manage its business processes

Potential for innovation

It is in the light of the aforementioned gap that the current research is focusing. Since simulation is a technique that permits the analysis of different scenarios and hence the reduction of risk, it is deemed suitable to analyse the impact of electronic commerce in manufacturing business processes and serve as a design tool for this change.

From the initial gap analysis, we have selected the operate processes (Childe *et al.* 1994) as a starting point for the research since we think that are the processes that are directly involved in producing value for the customer and are more likely to be impacted by electronic commerce.

It is at this stage where the different aspects of the agenda are set. The research questions to be answered are:

- Is simulation suitable as a tool to analyse the effect of e-business implementation in the business processes of manufacturing companies.
- Can patterns be identified that characterise the e-business processes of manufacturing companies?
- Can re-usable simulation templates be derived from these patterns?
- What are the limitations, scope and range of applicability of these templates?
- What methodology must be followed when using simulation in this context?
- Identify generic performance measures for each one of these activities and whether there is a need for changing them to best serve the new business process structure.

The scope of the present research will be focused on "brick-and-mortar" companies that want to adopt e-commerce and will explore the modalities of internal, external and inter-organisational issues.

BACKGROUND

McFarlane *et al.* (2001) state "...remarkably little work has addressed the full impact of internet developments at the operational level of manufacturing companies". It can be argued that although a lot of effort has been devoted to study the interface aspects of e-business, there is very little evidence of research trying to understand the internal effects of adopting e-business strategies. Before continuing

with this discussion, we will first define what e-business is and how can it affect the business processes of manufacturing companies.

E-business.

E-business and e-commerce have been defined in different ways, sometimes conflicting or incomplete. In order to set the context of the research and avoid confusion, some definitions will be presented. For the purpose of our research, e-commerce has been defined as “the buying and selling of goods and services via electronic mediums such as the Internet” (Bontis & De Casto 2000).

E-business, on the other hand, is defined as “the transformation of key business processes through the use of Internet technologies” (Chaffey 2002). E-business is now usually referred as being comprised of applications such as e-commerce, business intelligence (BI), customer relationship management (CRM), supply chain management (SCM) and enterprise planning (ERP) amongst other (Strauss & Frost 2001).

As can be appreciated from the previous definitions, e-business presents a more complex scenario than solely e-commerce, having the potential of affecting a greater number of internal operations in a business. The complex situations that could derive from the application of e-business must be analysed and understood before going ahead with the project. New technologies have failed because not enough analysis of the effects of such implementations was carried out before starting the project (Larsen & Myers, 1999, Hlupic & Robinson 1998).

Characteristics of electronic markets

Fryer (2001) identifies the characteristics of the market in an e-business environment: More erratic and difficult to predict demand, last-second orders and the expectation of overnight fulfilment, a removal of the slack that traditional processes have between operations and the uncertainty to back-end members of the supply chain members about order fluctuations, reducing their responsiveness. It has been stated “the Internet has created some new industries... however, its greater impact has been to enable the reconfiguration of existing industries that had been constrained by high costs for communicating, gathering information or accomplishing transactions” (Porter 2001).

This reconfiguration is what we aim to study, analysing the effect that e-business will have not only on the external environment of companies, but also in the way they operate internally. We believe that simulation can help this analysis and that business processes should be the framework within which this analysis should be carried out.

BUSINESS PROCESS MANAGEMENT (BPM)

The Business Process Simulation (BPS) area emerged from a need to analyse Business Process Re-engineering (BPR) efforts, especially after the initial low success rate (Hlupic & Robinson 1998). Without going into too much detail (since

the methodology is well established and widely known), a brief description of the background in Business Process Management will be given in order to set the context of the work developed.

Business Processes

Business processes are defined as “The logical organisation of people, materials, energy, equipment and procedures into work activities designed to produce a specified end result” (Davenport & Short 1990). In the 1990’s, BPM had a profound impact on businesses by changing the way in which these businesses look at their activities, moving from a functional (departmental) perspective to a cross-functional, team based view (a more detailed review of BPM and BPR is presented in (Albores *et al.* 2002a). Paul *et al.* (1999) state that “process based organisational analysis implies a ‘systemic’ view of organisations, characterised by identifiable components with complex relationships between them”

In order to understand this complexity, Childe *et al* (1994) described a set of generic business process models for manufacturing enterprises based on the CIM-OSA business process architecture (Figure 2). In their framework, Childe *et al.* (1994) identify three main classifications of business processes. Operate Processes are those which are related directly to satisfy the requirements of external customers, Manage Processes are those related with strategy and business planning and Support Processes act in support of the other two types of processes. This framework will be used to analyse the impact of electronic business in the business processes of manufacturing companies, focusing on the Operate processes and specially on the order fulfilment process.

Figure 2 - CIM-OSA business process architecture

Business Process Re-engineering

Business Process Re-engineering has been defined in many ways. As an example, two definitions are presented.

“The fundamental rethinking and radical design of business processes to achieve dramatic improvement in critical, contemporary measures of performance such as cost, quality, service and speed” (Hammer and Champy 1993)

“Is concerned with fundamentally rethinking and redesigning business processes to obtain dramatic and sustaining improvements in quality, service, cost, lead-times, outcomes, flexibility and innovation” (Irani et al 2000)

From the previous definitions, we can find characteristics such as radical, dramatic, fundamental rethinking. This was the way in which the pioneers of BPR considered that the changes should be done. Melao & Pidd (2000) gathered evidence that differentiates the first generation of BPR practitioners (Inspirational, Radical, broad, IT led, hard, etc) from the second (Methodological, continuous improvement, focused, IT enabled, soft, etc). This change is reflecting the consideration of softer aspects (people, strategy) over the traditional, mechanistic approach to re-engineering.

BUSINESS PROCESS SIMULATION

Modelling and simulation

Modelling of business process has been a requisite for Business Process Re-engineering. The initial modelling approach was to create a static model of the process, for example flowchart diagrams, IDEF0, DFD, etc. Later, the need for a dynamic representation of the business process and the change in these processes over time was identified. This led to the use of simulation as a tool for analysing and “predicting the outcome of radical change of BPR” (Hlupick 1998).

A simulation model is a model that mimics reality (Robinson 1994). Ball (1996) defines simulation in a more complete manner: “simulation is the technique of building a model of a real or proposed system so that the behaviour of the system under specific conditions may be studied. One of the key powers of simulation is the ability to model the behaviour of a system as time progress”. Among the characteristics of simulation are:

- Dynamic
- Stochastic
- The main benefits obtained from simulation include (Robinson,1994):
- Risk reduction,
- Greater understanding of the dynamic of the system,
- Low cost compared with real life experimentation,

- Repeatability
- Identification of dynamic and transient effects.

Suitability of Simulation for Business Process Modelling

Taking into account the above-mentioned characteristics, simulation has been identified as a suitable technique to help the implementation of BPR projects (Wolsthenholme 1997; Melao & Pidd 2000; Strader et al 1998; Irani et al 2000; Fathee *et al.* 1998, Hlupic & Robinson 1998; Denis *et al.* 2000; Greasly 2000, Kettinger *et al.* 1997).

The main characteristics of simulation reported to be useful in business process modelling are:

- Provides quantitative information for decision making.
- Analyses the dynamic interdependency of activities and entities within the process.
- Can model technical and human resources.
- Conducting “What if” experiments.
- Enhancement of corporate capabilities to achieve in-depth understanding of internal process performance and correct allocation of resources (Fathee et al 1998).
- Simulation can be used to analyse process change or to design completely new processes and test the future behaviour of the real system
- Incorporates the stochastic nature of business processes and the random behaviour of their resources (Irani 2000).
- Allows the participation of non-technical staff on BPR teams since it has a highly visual display of the process and its functioning.

Reported applications

Different applications have been reported in business processes, and although they claim that is a business process application, it has been mainly restricted to the operational side (i.e. manufacturing). From the range of applications reported as business process simulation, five groups have been identified (Albores *et al.* 2002b).

- *Conceptual business process simulation.* This group of authors deal mainly with the identification of the requirements for simulating business processes. In this group we find (Hlupic & Robinson 1998, Paul *et al.* 1999, Fathee *et al.* 1998, Tumay 1996, Jones 1995). They have identified the importance of hierarchical capabilities within simulation software, the need of a good process model interface (usually linked to standards like IDEF0, IDEF3 or flowcharting) and the need to have flow objects, resources, activities and routings in order to better represent business processes.
- *Manufacturing systems simulations.* This group include applications that are focused on the physical flow of entities through a series of workstations. An example application is (Irani *et al.* 2000). Although it is presented as a business process simulation, it lacks the flow of information and cross-functional activities that should characterise a business process (Albores *et al.* 2002a).

- *Process Specific Simulations.* This group includes those authors that have undertaken the simulation of a specific process (e.g. Service provision process) within an organisation. Examples of this include (Greasly 2000; Dennis *et al.* 2000).
- *Enterprise-wide simulations.* This type of simulation refers to the interaction between different actors (processes) within an enterprise. Examples of this category are the Whole Business Simulator (Love & Barton 1996) and the application of simulation to understand and improve the coordination between three different plants of the same automotive company (Hlupic & Robinson 1998).
- *Supply chain-wide simulations.* Related to the simulation of coordination between companies across the supply chain. An example is the analysis of demand management policies (Make to Stock, Make to Order, etc) and its implications for the members of the supply chain (Strader *et al.* 1998).

As can be seen from the wide variety of applications, business process simulation is a well-established tool and can be used at any level of the enterprise with different degree of detail and level of scope. It is a particularly useful tool for the analysis of system change and provides elements of comparison between different alternatives to the design of these changes. This technique can be applied to study the impact of new ways of doing things; especially those that have a big impact in the ways business operate, such as e-business.

The remaining of this paper will deal with the description of two case studies carried out to apply the concepts expressed in this paper and make a comparison between two different scenarios (Make to Order and Make to Stock) and the implications of e-business in both scenarios.

CASE STUDIES

Case research was chosen as an appropriate research method at this stage of the project since "... the case method lends itself to early, exploratory investigations where the variables are still unknown and the phenomenon not at all understood" (Voss *et al.* 2002). Being the nature of the research question an exploratory one justifies even further the use of a case study. In addition, according to Mukheerjee *et al.* (1999) "cases are particularly useful when there is uncertainty in the definition of constructs".

So far, two case studies have been carried out. These two cases are part of the ongoing research and were used to shed some light on the research questions and test the proposed approach.

Case 1: Waterco. Make to stock manufacturer

The first case study refers to a mineral water manufacturer that has won a contract for the manufacture of an own label for one of the biggest retail stores in the UK, a move that will double the production in the plant. This will lead to an increase in warehouse capacity, currently under development, and an increase in production capacity in order to cope with this demand. This increase in the number of

transactions has led to the company to search areas of improvement in their order processing time; analysing options like introducing an Internet based ordering system (in the customer side) and e-enabling part of the purchasing process (in the supplier side).

Process description

The process starts when an order arrives. There are three types of order arrivals. Telephone, Fax and EDI. Telephone and Fax orders are captured in a card and then logged into the ERP system (MAX). EDI orders are automatically logged into the system when they are “pulled” from the EDI server. A sales agent then calls the customer to book a delivery time and adds this information to the order file. Approximately every two hours, the batch allocation process is run. This automated process assigns a specific pallet/group of pallets to the order, accordingly to the required quantity and type of product. The process allocates about 20 orders (hence the “batch” name) each time it is run and takes about 20 minutes to complete.

After the batch allocation process, the order is split. One part goes to the finance department and waits until conditions are fulfilled to send out the invoice. Meanwhile, the warehouse department receives its copy of the order, runs a batch process similar to that described above, but with the purpose of finding which orders are “cleared” for delivery (i.e. they don’t have a credit problem or similar issues). Once having the valid orders, the warehouse department assigns the haulier that will handle the shipment (based on heuristic rules) and generate a Purchase Order for Haulier (POH) in the system. The POH is then printed and accumulated on a tray. Once a number of orders (20 - 25) are stored in the tray, they are faxed to the Hauliers, so they can make the necessary planning for the trucks to come on the specified day, pick the orders and deliver to the customer. Once the orders have been delivered, the haulier sends a delivery note to the company. This delivery note is tied to the customer order and the invoice is sent out to the customer.

Project Scope

The scope of the project is the exploration of changes in the way the POHs are sent to the haulier. Alternatives such as Email, e-fax and XML are to be explored as technical solutions for this end. From the point of view of the process modelling, these transactions are going to be considered equivalent in the model.

In addition, an exploration of the future possibilities of reception of orders via electronic means (XML) is going to be carried out. Different scenarios (order mixtures) are going to be analysed, as well as the mixed effect of e-order taking and e-POH. A Summary of the experiments is described below:

Purchase order for haulier

Comparison between traditional (Fax) and electronic processing (Auto Fax, email, XML).

Receive Order

Comparison between different ratios electronic vs. traditional order
20% E-orders, 80% traditional orders (Current)

50% E-orders, 50% traditional orders

80% E-orders, 20% traditional orders

The selected metrics for the comparison of results are:

- Processing time
- Throughput
- Staff utilisation
- Cost (informative purpose only)

The model was built in sequential stages. Three main sub-processes were identified within the whole process and using the capabilities of the selected simulation software (Simprocess V2.2.2), were created as high-level processes within which specific activities would be detailed. The High level representation of this sub-processes can be seen in Figure 3.

Figure 3 - High-level Model of the Business Process

Experiment Results

By changing the way the process operates inside the high level modules and changing manual intervention in the latest stages of the purchasing process to automated, electronic based order dispatching, a reduction in resource utilisation and overall processing time were achieved. The results can be seen in table 1

Table 1 - Comparison between current and e-enabled purchasing process.

	Current	e-process
Units processed	2052	2052
Units remaining in system	54.4	36
Processing time /unit	272 min	215 min
Staff Utilisation (POH)	77.66%	17.90%
Cost/unit	£ 4.58	£ 2.9
Cost/month	£ 8755	£ 5650

Case 2: LabelCo. Make to order Manufacturer

The second case study refers to a Label manufacturer. This manufacturer was the first and is now the largest digital label printer in the United Kingdom. They

specialise in the production of labels and labelling systems for industry and commerce. Products include prime labelling for a wide range of products, including computer labels, bar code labels, identification labels, laser labels, and continuous labels of any sort. Products use a wide range of materials from paper, board, Computer Imprintable Film, Film, metalised film, PVC, etc. This manufacturer supplies especial labels for the water manufacturer of case 1, amongst other clients.

The simulation model was built to analyse the effect of introducing new e-business strategies, specifically geared towards customer interaction and involvement along the design and production process. Having currently order-processing lead times of up to 14 days, they plan to reduce this to less than 5 days introducing e-business. Figure 4 outlines this process.

Figure 4 - Label Manufacturer process

The process followed is: A client enquires about a label. The client manager takes the specification and files it in a predetermined label specification sheet. This sheet is passed to technical planning and a quotation generated. The quotation is checked and amended if required by the marketing manager. Technical planning updates the quote and it is sent to the client manager in order to be sent to the customer. The customer accepts or rejects the quote. In the former case, the customer sends an artwork and an order is raised by the client manager. Technical planning creates a proof and schedules the job. The client manager sends the proof to the client for verification. Once the client accepts the proof, pre-production starts and then the labels are made.

Data collection was made through interviews with the process actors and through time keeping data sheets attached to the order and that followed it through

the process (this part of the process was carried out by an internal facilitator). The model was built in Simul8 V7.

The results of this analysis show that implementing a workflow application would greatly reduce the time the orders spend being processed, but it will build a bottleneck in the first stages of production. Similarly, allowing the customers to have access to the different stages of the production process will have the effect of removing the slack that is currently inbuilt in the system and would put strain on the customer managers and the technical planners.

Coming back the Figure 2, we identify in this case study the Manage customer and Manage order/enquiry processes, as well as part of the Plan Order fulfilment process. Once again, the level of detail presented in Figure 2 does not show the differences between the traditional and the e-business process.

Comparisons and challenges in each case study.

The idea behind selecting different case studies is threefold. First, to test the applicability of the proposed approach across a number of industrial applications. Second, to analyse the issues that would arise from different e-business applications implemented in different types of production systems. Finally, to test different software tools and their suitability for simulation of e-business processes.

Production type and e-business application

The case studies represent two different demand response modes: make to stock (MTS) and make to order (MTO). Hill (2000) defines MTS companies as “those that complete or purchase items ahead of demand and then meet orders from finished goods inventory” and MTO businesses as “those that are usually involved in the provision of special (that is, will not be repeated) products and services. In addition, some companies decide to meet demand for standard (that is, repeat) items only on a MTO basis. Either way, an MTO response means that inventory will not be held either as part-finished or finished items. What may be held in stock are the material and components that form all or part of an item.”

The effect of e-business in the shop-floor was more evident in the MTO scenario. In the MTS company (Waterco) the application of e-business was focused in the back end of the business and in the analysis of incoming orders, the buffer that stock provides helped to mitigate the effects that e-business had on the running of the manufacturing shop-floor. On the other hand, in the MTO company (Labelco), the introduction of e-business had a more direct effect in the planning and running of the shop floor.

From the modelling point of view, the difference between the MTS and MTO scenarios meant that the scope of the models had to be different in each case. In the MTS system the model did not include the shop floor, reducing the complexity of the model. This decision was made taking into account the fact that the company has a nearly 100% stock cover. Labelco needed to study the effect of customer intervention at different stages of the process hence the decision of including not only the administrative processes, but also the manufacturing part, was made.

The e-business application selected in each case was focused in different task. Waterco needed an e-procurement application, while Labelco were interested in a

workflow type of system. The e-procurement application dealt with the link with suppliers while the workflow system affected more directly the internal way of working.

Software

The software used in the two applications was different. In the Waterco case study, a business-process oriented software was used. For the Labelco case study, a general-purpose simulation software was used. The idea behind using two types of simulation tools was to analyse the suitability of existing tools for the modelling of e-business.

As far as the modelling of e-business, both tools presented useful characteristics for the simulation of e-business, without being completely suitable for this application. Amongst the useful characteristics found in the business process oriented software are: the ability to model hierarchical processes and the inclusion of functions such as branch and merge, split and join, synchronise. From the general-purpose software, we identify the following characteristics suitable for this exercise: a number of routing options, general purpose options such as change over and set-up times, especially useful for the manufacturing side of the model.

Ball *et al.* (2002) state that “the modelling of physical as well as information flows represents an important feature for e-business modelling.” Although both tools are capable of dealing with this issue, none of the tools made it straightforward, requiring twinning the existing capabilities of the tools to model both information and physical flows, which many times occurred concurrently. Accordingly, Ball *et al.* (2002) indicate that representing processes at different levels of abstraction is typically down to the software user’s skill, implying that depending of the ability of the modeller, the modelling of e-business will be easier or more difficult. This inherent ability of the modeller does not preclude the need for a simulation tool that makes the modelling of e-business more accessible to users with little or null experience in simulation tools.

Extent of company deployment (how do they fit in my classification)

Regarding the classification presented earlier in the paper, the two case studies fit in different categories, although in general terms, they share some aspects. In the case of Waterco, the order purchase for haulier fits in the process-specific classification. On the other hand, the Labelco case study has the characteristics of an enterprise-wide simulation. It is worth mentioning that by introducing e-business to the modelling task, both case studies present also an element of interface with the external world. In the first case this interaction is mainly with suppliers, although some analysis of customer order patterns was carried out. In the second case, the interface is with customer, who have a direct impact on the process. As a consequence of these case studies, it is thought that the five types of business process simulation presented would require the addition of the interface element to take into account the effect of e-business. This addition may lead to a new classification of e-business process simulations.

Modelling of human involvement

Despite the high degree of automation present in businesses, key decisions are still being made by humans. Modelling challenges occur such as representing decision making of employee of whether to, say, de-allocate stock from one customer order to be able to supply stock to a key account customer. This challenges represent an important part of the model, since this judgements are likely to have a great impact in the performance of the system. In the first case study, agreements were reached as to which scenarios to take into account and how likely the occurrence of this scenario was. These estimates were then fed to the model. On the other hand, the human decisions were modelled based on historical data collected during the data gathering phase.

Independently of the approach used, it is important to reach as consensus with the process actors and make very clear the assumptions made. This is equally applicable to the modelling of the new electronic transactions, for which many times the dynamic aspects (e.g. lead-times) are unknown.

CONCLUSIONS

A simulation approach for the quantitative analysis of the effect of e-business in the business processes of manufacturing companies has been presented. The argument behind the approach is that it is needed to evaluate the effect of collaborative tools such as e-business not only at the front end of manufacturing businesses or at the interface with other companies, but also to analyse how this collaboration will affect the way of running the back end operations.

Two case studies were presented, one in a make-to-stock company and another in a make-to-order business. The two case studies illustrated the usefulness of the proposed approach and were used also to analyse some issues in order to look for generic aspects of e-business simulation.

Commonalities and differences were found in the case studies. First, it was identified that the effect of e-business was more notorious in a MTO scenario, since the stock existent in a MTS scenario serves as buffer between manufacturing operations and the changing demand patterns that are inherent to electronic markets. Second, the need to model both information and physical flows was identified. Third, challenges arose in both case studies regarding the modelling of human decisions and electronic transactions. A clear agreement must be reached between the modeller and the process actors regarding the way of modelling these issues.

Two software tools were evaluated and both present useful characteristics for e-business simulation. However, it was observed that a modification of the tools is required in order to make it more accessible to the simulation non-expert.

From the work presented, we can conclude that simulation is a suitable tool for the analysis of e-business implementation, answering the first research question. Future work will involve the development of a set of generic e-business processes for use in simulation and the testing of such processes, as well as the development of the methodology that will accompany these processes and that will guide the use of simulation for the analysis of e-business effects on business processes.

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