SIMULATION MODELLING OF BUSINESS PROCESSES

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ABSTRACT

Increasingly, organisations need to adapt to new conditions and competitive pressures. Various change management approaches such as business process re-engineering have been developed to meet this perceived need. This paper investigates the potential of simulation modelling for modelling business processes. After a discussion on business processes related issues, an overview of business process modelling methods is presented. The usability of simulation modelling for evaluating alternative business process strategies is investigated. Finally, a framework for business process simulation is proposed.

INTRODUCTION

It is claimed that the increasing competitive pressures that organisations face encourages them to minimise the time it takes to develop the product, bring products to market and service customers whilst maximising profits. This pressure has made Business Process Re-engineering (BPR) a popular topic in organisational management and created new ways of doing business (Tumay, 1995). BPR relates to the fundamental rethinking and radical redesign of an entire business system to achieve significant improvements in performance of the company.

Many leading organisations have conducted BPR in order to improve productivity and gain competitive advantage. For example, a survey of 180 US and 100 European companies found that 75% of these companies had engaged in significant re-engineering efforts in the past three years (Jackson, 1996). However, despite the number of companies involved in re-engineering, the rate of failure in re-engineering projects is over 50% (Hammer and Champy, 1993). Some of the frequently cited problems related to BPR include the inability to predict the outcome of a radical change, difficulty in capturing existing processes in a way that can be seen by multidisciplinary team members, shortage of creativity in process redesign, cost of implementing the new process, or inability to recognise the dynamic nature of the processes.

Many authors argue that one of the major problems that contribute to the failure of BPR projects is a lack of tools for evaluating the effects of designed solutions before implementation (Paolucci et al, 1997), (Tumay, 1995). Mistakes brought about by BPR can only be recognised once the redesigned processes are implemented, when it is usually difficult and costly to correct wrong decisions. Although the evaluation of alternative solutions might be difficult, it is essential in order to reduce some of the risks associated with BPR projects.

Simulation modelling appears to offer great potential for modelling and evaluating alternative business processes. Simulation uses a symbolic representation of processes in order to determine the path and flow of state transitions in ways that can be made persistent, replayed, dynamically analysed and reconfigured into alternative scenarios (Scacchi, 1997). For example, simulation models can dynamically model different samples of parameter values such as arrival rates or service intervals which can help in the discovery of process bottlenecks of and suitable alternatives. Simulation models can provide a graphical display of process models that can be interactively edited and animated to show process dynamics.

This paper investigates the potential of simulation modelling to model business processes. We start by a discussion related to business processes and their definitions. A brief overview of business process modelling methods is presented. We then investigate the usability of simulation modelling for evaluating alternative business process strategies, and propose a framework for business process simulation. The conclusions outline the main findings of this research.

DEFINING BUSINESS PROCESSES

There is no clear or agreed definition of "business process" in the literature. For example, Hammer and Champy (1993) define a process as "a set of activities that, taken together, produces a result of value to a customer." According to Davenport and Short (1990) a business process is "a set of logically related tasks performed to achieve a defined business outcome". Pall (1987) defined a process as "the logical organisation of people, materials, energy, equipment, and procedures into work activities designed to produce a specified end result (work product)."

The BPR on-line learning centre states that "business processes are simply a set of activities that transform a set of inputs into a set of outputs (goods or services) for another person or process using people and tools." Ferrie (1995) defines processes as being "a definable set of activities which from a known starting-point achieve a measurable output to satisfy an agreed customer need." On the other hand, Earl (1994) define a process as "a lateral or horizontal form, that encapsulates the interdependence of tasks, roles, people, departments and functions required to provide a customer with a product or service."

According to Omrani (1992) a process is "a cycle of activities, which taken together achieve a business objective". Davenport and Short (1993) define a process as "a structured, measured set of activities designed to produce a specified output for a particular customer or market. It implies a strong emphasis on how work is done

within an organisation". In another publication, Davenport (1993) defines a process as "an ordering of work activities across time and place, with a beginning, an end, and clearly identified inputs and outputs."

Saxena's (1996) definition of a business process declares that a process is "a set of inter related work activities characterised by specific inputs and value added tasks that produce specific outputs". Talwar (1993) defines a process as "any sequence of pre-defined activities executed to achieve a pre-specified type or range of outcomes." According to Alter (1996) a business process is referred to as "a related group of steps or activities that use people, information and other resources to create value for internal or external customers. The steps are related in time and place, have a beginning and end, and have inputs and outputs".

It is apparent from an analysis of the above definitions of business processes that there is no consensus. However, some common elements can be identified in a majority of definitions. These elements relate to the process itself (usually described as transformation of input, workflow, or a set of activities), process input, and process output (usually related to creating value for a customer, or achieving a specific goal).

Re-engineering business processes involve changes in people, processes and technology over time. As these changes happen over time, simulation appears to be a suitable process modelling method. The interaction of people with processes and technology results in an infinite potential number of scenarios and outcomes that are not possible to predict and evaluate using static process modelling methods.

BUSINESS PROCESS MODELLING TOOLS AND METHODS

There are multitudes of approaches, methodologies, and techniques to support BPR design efforts (Wastell et al, 1994), (Harrison and Pratt, 1993). Kettinger et al (1997) conducted an empirical review of existing methodologies, tools, and techniques for business process change and developed a reference framework to assist positioning of tools and techniques that help in re-engineering strategy, people, management, structure, and technology dimensions of business processes. Some of the most widely used process modelling techniques includes IDEF, role activity diagramming, process flowcharting, and hierarchical coloured Petri nets (Kettinger et al, 1997). Although simulation is also mentioned as one of the modelling methods in a comprehensive survey conducted by Kettinger et al (1997), the authors identified a need for more user-friendly multimedia process capture and simulation software packages that could allow easy visualisation of business processes and enable team members to participate in modelling efforts. Table 1 summarises the main types of business processes modelling tools available as presented in Gladwin and Tumay (1994).

Type of Modelling Tool	**General Description**	**Examples**
Flow Diagramming Tools	These tools help define processes and work flows by connecting text descriptions of processes to symbols.	ABC Flowcharter, Process Charter, EasyFlow, FlowCharting3.

CASE tools	These tools provide a conceptual framework for modelling process definitions and hierarchies.	Design/IDEF, Workflow Analyser, Business Design facility, Action Workflow.
Simulation Modelling Tools	These tools provide dynamic, stochastic and animation analysis capability	ServiceModel, SimProcess, Extend+BPR, BPMAT

Table 1: Business process modelling tools

Business process modelling tools are continuously being released on the software market. Many of these tools represent business processes by graphical symbols, where individual activities within the process are shown as a series of rectangles and arrows.

Most software tools for business process modelling have an origin in a variety of process mapping tools that provide the user with a static view of the processes being studied. Some of these tools provide basic calculations of process times. More sophisticated tools allow some attributes to be assigned to activities and enable some sort of process analysis. However, most of these tools are not able to conduct "what if " analysis, show dynamic changes in business processes, or evaluate the effects of stochastic events and random behaviour of resources. All of these are possible using simulation models of business processes. Simulation software tools are able to model the dynamics of the processes, such as the build up of queues, and show it visually, which can then enhance the generation of creative ideas concerning the redesign of the existing business processes.

Analysis of the literature reveals that there no comprehensive, scientifically grounded design methodology to structure, guide, and improve organisational design efforts. Many authors argue that one of the major problems that contributes to the failure of business process change projects is a lack of tools for evaluating the effects of designed solutions before implementation (for example, Paolucci et al 1997, Tumay 1995). Mistakes about brought by business change can only be recognised once the redesigned processes are implemented, when it is usually difficult and costly to correct wrong decisions. Although a complete evaluation of alternative solutions is difficult, some attempt is essential in order to reduce some of the risks associated with business change projects. This argument is in line with van Meel and Sol (1996), who advocate the development of computer-based models of business processes as a crucial mechanism to support the process of experimentation with alternative business structures. Such models could be particularly useful for prototyping and accelerating process conceptualisation. This can then eliminate costly and time consuming trial and error approaches usually taken in the absence of adequate business process modelling tools.

Simulation is one of the most widely used techniques in operational research and management science (Law and Kelton 1991). However, there are relatively few examples of using simulation for business process modelling available in the literature. A majority of these publications were written by simulation modelling practitioners rather than business analysis specialists. So, the potential of simulation for business

process modelling has yet to be recognised by the business community.

SIMULATION AND BUSINESS PROCESS MODELLING

The basic idea behind simulation is simple (Doran and Gilbert, 1994): We wish to acquire knowledge and reach some informed decisions regarding a real-world system (the business). But the system is not easy to study directly. We therefore proceed indirectly by creating and studying another entity (the simulation model), which is sufficiently similar to the real-world system so that we are confident that some of what we learn about the model will also be true of the system. In other words, the simulation model is used as a vehicle for experimentation, often in a 'trial and error' way to demonstrate the likely effects of various policies. Those policies producing the best results in the model should be implemented in the real system (Pidd, 1992).

Simon (1973) argues that one of the most important uses of computers is 'to model complex situations and to infer the consequences of alternative decisions to overcome bounded human rationality'. We argue that computer-based models of business processes can help overcome the inherent complexities of studying and analysing businesses, and therefore contribute to a higher level of understanding and thereby improving these processes.

In terms of the business environment, simulation models usually focus on an analysis of specific aspects of an organisation, for example production or finance. Perhaps the most widely known application area of simulation in the business arena is for modelling manufacturing operations, where the complexity and dynamic behaviour of the system is the main reason for using simulation to facilitate system design and assess operating strategies (Carrie, 1988). Examples of the use of simulation for manufacturing, production and operations management can be found in (Hlupic and Paul, 1994) and (Ceric and Hlupic, 1993). Another category is financial modelling, which is mainly concerned with risk analysis (Seila and Banks 1990). Only a few articles focus on modelling the whole spectrum of organisations and adopt a process-based approach in so doing.

The use of business process modelling tools is usually focused on modelling current business process, without a systematic approach to evaluating business process alternatives. Gladwin and Tumay (1994) discovered that over 80% of BPR projects used static flowcharting tools for business process modelling. The static modelling tools, which are predominately used, are deterministic and do not enable the evaluation of alternative re-designed processes.

Simulation models, on the other hand, can incorporate and depict the dynamic and random behaviour of process entities and resources. The physical layout and interdependencies of resources used in the processes under consideration can be shown visually, and the flow of entities among resources can be animated using simulation as a modelling tool.

A FRAMEWORK FOR BUSINESS PROCESS SIMULATION

Simulation models provide quantitative information that can be used for decision-

making. As such, they are regarded as problems understanding tools rather than problem solving tools. There are several characteristics of simulation that make this method suitable for business process modelling:

- A process approach in simulation modelling terminology relates to a time-ordered sequence of interrelated events which describes the entire experience of an entity as it flows through the system (Law and Kelton, 1991). This approach can be related to some of the definitions of business processes presented in section 2 above.
- Simulation models can be easily modified to follow changes in the real system and as such can be used as a decision support tool for continuous process improvement.
- A simulation model of non-existing business processes can be developed and used for process design (rather than for redesign).
- Simulation models can capture the behaviour of both human and technical resources in the system.
- Simulation models can incorporate the stochastic nature of business processes and the random behaviour of their resources.
- The visual interactive features of many simulation packages available on the market enable a graphical display of the dynamic behaviour of model entities, showing dynamic changes in state within processes.

The benefits of using simulation for business process modelling are numerous. For example, organisations can react more quickly to market changes, because simulating the effects of redesigned processes before implementation can improve the chances of getting the processes right at the first attempt. Visual interactive simulation backed up by a variety of graphical output reports can show the benefits of redesigned processes, which can be used for business process re-engineering "buy-in", and for communicating the structure of new processes to other employees. Simulation can be used for focusing "brainstorming" meetings, where various new ideas can be tested using a simulation model, and informed decisions can be made. A simulation model of business processes can determine a potential bottleneck area and ascertain which resources are critical.

The process of developing simulation models of business processes can be divided into several distinct steps that have to be followed, from the identification of a need, to providing recommendations. Although these steps are necessarily described sequentially, they are executed iteratively, and several individual steps are usually repeated until they produce a suitable outcome. A framework for carrying out business process simulation consists of the following steps (summarised in Table 2):

Step 1 - Defining Modelling Objectives

Once it has been decided to use simulation for business process modelling, it has to be decided what is the required outcome of modelling and which information the model should provide. For example, the objective of modelling might be to evaluate the effects of downsizing or allocating particular tasks within processes to different employees.

Step 2 - Deciding on Modelling Boundaries

In this stage, it has to be decided which processes (or parts of a large process) should be incorporated in the model. This is to be determined on the basis of the importance

of certain processes or a need to redesign inefficient processes, and on the basis of the suitability of particular processes to be captured in a simulation model.

Step 3 - Data Collection and Analysis
Depending on the scale of modelling, a certain amount of important data about the processes being modelled needs to be collected and analysed in order to be incorporated in a model. Data is usually collected through discussions with experts and particularly with people involved in the processes to be modelled, through observation of the existing processes and through studying the documentation about processes. Data collected needs to be analysed using standard statistical procedures such as distribution fitting (Law and Kelton, 1991).

Step 4 - Business Process Simulation Model Development
Once the relevant data about the business processes is collected and analysed, a simulation model is developed using a simulation software package. This should be done through an iterative process where a simple model is initially developed, which is then expanded and refined until an acceptable model is obtained.

Step 5 - Model Testing
After each iterative step in the model development, "models in progress" should be thoroughly tested using as many model verification techniques as feasible. Some of the most commonly used verification approaches include black box validation (for example testing model components) and white box validation (for example testing input distributions, static and dynamic logic) (Pidd, 1992).

Step 6 - Model Experimentation
After acceptable testing, experimentation with the model can commence. Formal experimental design seems to be appropriate where there are a number of alternative ways of performing the same process (Darnton and Darnton, 1997). General rules related to the design of experiments include:

- random errors should be reduced,
- experiments should be designed in such a way to include a wide range of alternatives so that recommendations could be valid for a range of organisational units,
- the experiment should be as simple as possible,
- a sound statistical analysis should be applied without making unrealistic assumptions related to the nature of business processes.

Step 7 - Output Analysis
Output results obtained during experimentation should be analysed using standard statistical techniques for simulation output analysis (Law and Kelton, 1991) related to the estimation of the values of the output variables.

Step 8 - Business Process Change Recommendations
The simulation model output analysis is used as a basis for making recommendations regarding business process change or improvement.

Step	Description
1	*Defining Modelling Objectives*
2	*Deciding on Modelling Boundaries*
3	*Data Collection and Analysis*
4	*Business Process Simulation Model Development*
5	*Model Testing*
6	*Model Experimentation*
7	*Output Analysis*
8	*Business Process Change Recommendations*

Table 2: A framework for business process simulation

SUMMARY AND CONCLUSIONS

This paper investigated the potential of simulation modelling for modelling business processes. Following a discussion related to business processes and their definitions, a brief overview of business process modelling methods was presented. The usability of simulation modelling for evaluating alternative business process strategies was investigated, and a framework for business process simulation proposed.

There are many reasons why simulation modelling should be used as a process modelling tool. For example, a new business process might involve a decision about capital investment that is difficult to reverse. It is usually too expensive to experiment with the real business processes, especially if business process change relates to the entire organisation. In many cases the variables and resources for new processes are not determined or understood, and the process of simulation model development can help in understanding some of these issues. The value of simulation depends on the model validity and the likelihood that the results of the model experiments would be replicated and implemented in the real processes.

Using simulation models can improve various skills, from technical to decision making. Good simulation models can lead to replicable results where assumptions are explicit and can overcome limitations inhuman reasoning (Darnton and Darnton, 1997). However, if models are not adequately developed and validated, then assumptions about the behaviour of real processes are likely to be wrong. It might also be difficult to achieve a required precision for a model due to a lack of data or to the highly unpredictable behaviour of some process resources. Finally, simulation model development might be costly. It takes time and requires specialist skills not widely available. In general, the decision to use simulation should be based on the modelling

objectives and on the available resources.

Regardless of the problems associated with business process simulation, the argument for using simulation as a business process modelling tool remains valid. A more widespread use of this method for business process modelling could increase the rate of success of BPR projects. Giaglis and Paul (1996) propose a computer aided BPR set of tools that would effectively and efficiently enable the engineering of the framework described in this paper.

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