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# BUSINESS PROCESS MODELLING AND ANALYSIS USING DISCRETE-EVENT SIMULATION

Vlatka Hlupic

Brunel University
Department of Information Systems
and Computing
Uxbridge
Middlesex UB8 3PH UNITED KINGDOM

Stewart Robinson

Operational Research and Systems Group
Warwick Business School
Warwick University
Coventry
CV4 7AL UNITED KINGDOM

## ABSTRACT

Globalisation and competitive pressure urge many organisations to radically change business processes. Although this approach can provide significant benefits such as reducing costs or improving efficiency, there are substantial risks associated with it. Using simulation for modelling and analysis of business processes can reduce that risk and increase the chance for success of Business Process Re-engineering projects. This paper investigates the potential of simulation modelling to be used for modelling business processes and supports the case for a wider use of simulation techniques by the business community. Following a discussion on business process modelling methods and tools, the usability of simulation modelling for evaluating alternative business process strategies is investigated. Examples of simulation models representing business processes are presented and discussed.

## 1 INTRODUCTION

The increasing popularity of simulation has resulted in its widespread use for modelling and analysis of systems in various application areas such as manufacturing, transport, logistics, communication networks, health care and military. Another, gradually emerging, application area of simulation is Business Process Re-engineering (BPR). BPR has become one of the most popular topics in organisational management creating new ways of doing business (Tumay, 1995). This management concept relates to the fundamental rethinking and radical redesign of an entire business system in order to achieve significant improvements in the performance of the company.

Various 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, regardless of 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 mentioned problems related to BPR include the inability to accurately predict the outcome of a radical change, difficulty in capturing existing processes in a structured way, shortage of creativity in process redesign, the level of costs incurred by implementing the new process, or inability to recognise the dynamic nature of the processes.

Several 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 realised once the redesigned processes are implemented, when it is too late, costly and probably impossible 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 could offer a great potential in modelling and analysing business processes. For example, these models can dynamically model different samples of parameter values such as arrival rates or service intervals which can help in discovering process bottlenecks and investigating 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 usability of simulation for modelling business processes. Various definitions of a business process are presented as well as a brief overview of business process modelling methods. The usability of simulation modelling for evaluating alternative business process strategies is investigated and the phases of business process simulation are outlined. Two examples of using simulation for business process modelling are also presented.

## 2 BUSINESS PROCESSES

There is no clear and agreed definition of a "business process" available in the literature. For example, Hammer and Champy (1993), defined a process as "a set of activities that, taken together, produces a result of value to a customer, whilst Davenport and Short (1990) define business process as "a set of logically related tasks performed to achieve a defined business outcome". According to Davenport (1993) a process is "an ordering of work activities across and place, with a beginning, an end, and clearly identified inputs and outputs".

Ferrie (1995) defines processes as being "a definable set of activities which from a known starting-point". According to Omrani (1992) a process is "a cycle of activities, which taken together achieve a business objective". 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)". Earl (1994) defined 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". On the other hand, 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" and Talwar (1993) defines a process as "any sequence of pre-defined activities executed to achieve a pre-specified type or range of outcomes."

The above definitions of business processes indicate that there is no consensus amongst the authors. 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, work flow, or a set of activities), process input, and process output (usually related to creating value for a customer, or achieving a specific goal) (Paul et al, 1997). Re-engineering business processes involves 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 number of possible scenarios and outcomes that are not possible to predict and evaluate using widely popular static process modelling methods.

## 3 AN OVERVIEW OF BUSINESS PROCESS MODELLING METHODS AND TOOLS

The number of organisations engaged in Business Process Re-engineering activities is increasing. As a result of this, there is a multitude of approaches, methodologies, and techniques to support BPR efforts (Wastell et al, 1994), (Harrison and Pratt, 1993). Kettinger et al (1997) conducted a survey of existing methodologies, tools, and techniques for business process change and developed a framework to facilitate referencing of tools and techniques that help in re-engineering strategy, people, management, and technology dimensions of business processes. Simulation is mentioned as one of the modelling methods in this survey, and 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 actively participate in modelling efforts.

Software applications for business process modelling are continuously being released on the software market. Many of these applications represent business processes by graphical symbols, where individual activities within the process are shown as a series of rectangles and arrows. A majority of 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. A few of these tools provide basic calculations of process times. Other, 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 model the dynamics of business processes and evaluate the effects of stochastic events and random behaviour of resources. On the other hand, 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 enhance understanding and help generate creative ideas on how to redesign the existing business processes. A physical layout and interdependencies of resources used in processes under consideration can be shown visually and the flow of entities among resources can be animated using simulation as a modelling tool.

Gladwin and Tumay (1994) discovered that over 80% of BPR projects used static flowcharting tools for business process modelling. Static modelling tools produce models which are deterministic and do not enable evaluation of alternative re-designed processes. The ProSci's 1997 Benchmarking Study (ProSci, 1997) analysed over 60 large international organisations who went through BPR exercise. The study investigated issues such as the reasons for redesigning business processes, methodology and modelling tools used, applying change management concepts, and the role of managers within BPR teams. It is interesting to note that the study revealed that less than 10% of the companies used simulation software as a modelling tool. Other tools used include flowcharting tools, spreadsheet, project management tools, word processors and database development tools. Many authors argue that one of the major problems that contribute 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).

## 4 BUSINESS PROCESS MODELLING USING SIMULATION

The potential of simulation for business process modelling has yet to be recognised by much of the business community. Business process simulation can help overcome the inherent complexities of studying and analysing businesses, and therefore contribute to a higher level of understanding and improvement. In terms of the business environment, simulation models usually, but not always, focus on the analysis of specific aspects of an organisation, such as manufacturing or finance. The first of the two examples in this paper does simply focus on manufacturing, while the second is much broader in scope.

### 4.1 Suitability of Simulation for Business Process Modelling

Simulation models provide quantitative information that can be used for decision-making and can be regarded as problem understanding rather than problem solving tools. There are several characteristics of simulation that make it suitable for business process modelling. For example, a process - based world view in simulation modelling terminology relates to a time-ordered sequence of interrelated events which describe the entire experience of an entity as it flows through the system which is comparable to the flow of entities through business processes. The flow of information within and between business processes can be modelled as the flow of temporary entities between processing stations. Furthermore, simulation models can capture the behaviour of both human and technical resources in the system. A simulation model can be easily modified to follow changes in the real system and as such can be used as a decision support tool for continuos process improvement.

It is apparent that the benefits of using simulation for business process modelling are numerous. For example, experimenting with a simulation model rather than implementing changes directly in the real process reduces the risk of making wrong decisions. The process of model building itself facilitates better understanding of the processes being modelled and helps identify feasible alternatives for change. Investigation of alternative process designs can significantly improve the chance of a successful BPR project, which can then result in capital cost reduction, better efficiency of processes, better service provided to customers and/or lead time reduction. Simulating the effects of redesigned processes before implementation improves the chances of getting the processes right at the first attempt. Visual interactive simulation models together with a variety of graphical output reports can demonstrate the benefits of redesigned processes which is useful for business process re-engineering approval. Simulation can also be useful for focusing "brainstorming" meetings, where various new ideas can be tested using a simulation model, and informed decisions can be made on the basis of model results.

### 4.2 The Process of Business Process Simulation

The process of developing simulation models of business process can be divided in several distinctive steps that have to be followed from the identification of a need for developing a simulation model of business processes to providing recommendations on the basis of simulation model output (Paul et al, 1998). Although these steps are sequential, they are iterative and several individual steps are usually repeated until they produce a suitable outcome. Figure 1 shows the steps of the process of business process simulation. The first step " Defining Modelling Objectives" relates to determining what is the required outcome of modelling and which information should be provided by the model. For example, the objective of modelling might be to evaluate the effects of downsizing or allocating particular tasks within processes to different employees. In the second step " Deciding on Modelling Boundaries", 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.

In the next stage ("Data Collection and Analysis"), a certain amount of important data about processes being modelled need to be collected and analysed in order to be incorporated in a model. Data are 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 need to be analysed using standard statistical procedures such as distribution fitting. The subsequent step "Business Process Simulation Model Development" relates to a simulation model development 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.

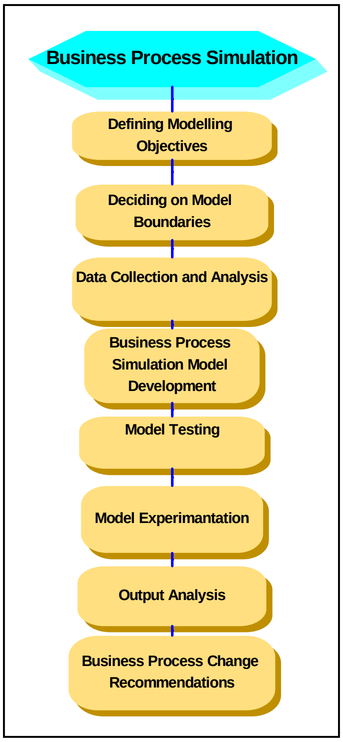


Figure 1. The Process of Business Process Simulation

In " Model Testing" phase, after each iterative step in model development, "models in progress" should be thoroughly tested using as many model verification and validation techniques as feasible. Once no significant problems are discovered during testing, experimentation with the model can commence ("Model Experimentation" phase*)*. Formal experimental design seems to be appropriate where there are a number of alternative ways of performing the same process, one of which is applied to each experimental organisational unit performing the process, and measurable observations are made for each unit (Darnton and Darnton, 1997). General rules related to 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 are valid for a range of organisational units, the experiment should be as simple as possible, and a sound statistical analysis should be applied without making unrealistic assumptions related to the nature of the business processes.

The next step relates to "Output Analysis". Output results obtained during experimentation should be analysed using standard statistical techniques for simulation output related to estimation of the values of output variables. Finally, in the "Business Process Change Recommendations" stage simulation model output analysis is used as a basis for making recommendations regarding business process change or improvement.

## 4.3 Examples of Simulation for Business Process Modelling

To illustrate how simulation modelling can aid business process reengineering efforts, two examples are now briefly discussed. These illustrate two extremes: one a high level model of a manufacturing organisation, the other a very detailed model, also of a manufacturing organisation.

One of the authors (Robinson) helped develop a high level simulation model of an automotive company's manufacturing operations. The company has three manufacturing plants within close proximity of one another. At the first plant car bodies are assembled and painted, at the second the engines and transmission and chassis are built and tested, while at the third the vehicles are assembled before being shipped to the customers. The company requested that a high level simulation model of their complete operation be developed in order to answer questions concerning their facility requirements, scheduling methods and the work flow around the plants. It was important that working methods were improved in order to meet increasing customer demand and to enable further product diversification. The model needed to predict the effect of changes on aspects such as the throughput and work-in-progress in the plants. Because the vehicles are made-to-order it was particularly important that the model could predict the time from receipt of orders at the factory, to completion of the assembled product.

The modelling approach adopted was to represent each of the key manufacturing facilities, more than 40 in all, using black-boxes (Robinson, 1994). In this approach a facility is represented as a time delay with no further detail included (figure 2). The time delay (or time to leave t) can be applied to individual entities (X) enabling process times and the effects of set-ups, breakdowns, re-sequencing and shift patterns to be represented. Where possible data from more detailed models of the facilities were used to determine the distribution of time delays. Otherwise a mixture of data analysis and expert opinion were used. Apart from modelling the physical facilities the information flows between facilities were also represented, for instance, triggers for engine build. In addition, the model included the receipt and issue of orders to and from the customer order bank.

The model represented business processes at two levels. On a macro level the complete model represented the business process of order receipt to completion of a finished product. On a micro level, each of the black-boxes represented a business process, with inputs of manufactured parts (e.g. engine blocks) and information (e.g. trigger for engine build), and outputs of the value added parts (e.g. complete engines) and further information (e.g. the engine specification).

Once completed the simulation proved a useful input to discussions on re-engineering the business process. For instance, a new production control system was to be introduced. The aim of this system was to control the complete production process. The improved understanding of the process gained from experimenting with the simulation model provided invaluable input to group discussions on the feasibility of various control options. In particular the model highlighted the complexities of controlling the flow of vehicles through the system with varying batch requirements and production constraints at different points in the process. In some instances vehicles were leaving the final assembly tracks 1,000 positions adrift from their original sequence in body-in-white.

Love and Barton (1996) propose a very different approach, known as the Whole Business Simulator (WBS), in which a very detailed model of a manufacturing enterprise is developed. The model consists of eight key segments (figure 3) and is broader in scope than the one above, including product design, suppliers, ancillary work and financial reporting as well as the manufacturing process.

It is also much more detailed, to the level of representing individual machines. Indeed, it is proposed that a company's actual systems, for instance, the materials planning and accounting systems, should be incorporated into the model. In this way a very detailed and accurate model of an organisation can be developed.

The authors have developed a demonstration version of WBS to illustrate its potential and demonstrate its viability. Using this model they describe an example in which the effects of a small change to the design of a product is simulated. Through experimentation, they are able to predict the effect of this redesign on the organisation's profits. The advantage of this approach is that it enables very detailed questions concerning process re-engineering to be answered. The disadvantage over higher level models is the development effort, which may be prohibitive for many re-engineering exercises

## 5 CONCLUSIONS

This paper investigated the suitability of simulation for business process modelling. A discussion related to business processes and their definitions was provided as well as a brief overview of business process modelling methods. The usability of simulation modelling for evaluating alternative business process strategies was investigated, and examples of business process simulation were provided.

Simulation should be used as a process modelling tool for many reasons. For example, a new business process might involve a decision about capital investment which is difficult to reverse. It is usually too expensive to experiment with the real business processes especially if business process change involves an entire organisation. In many cases the variables and resources for new processes are not determined or understood and the process of simulation modeling can help in understanding some of these issues.

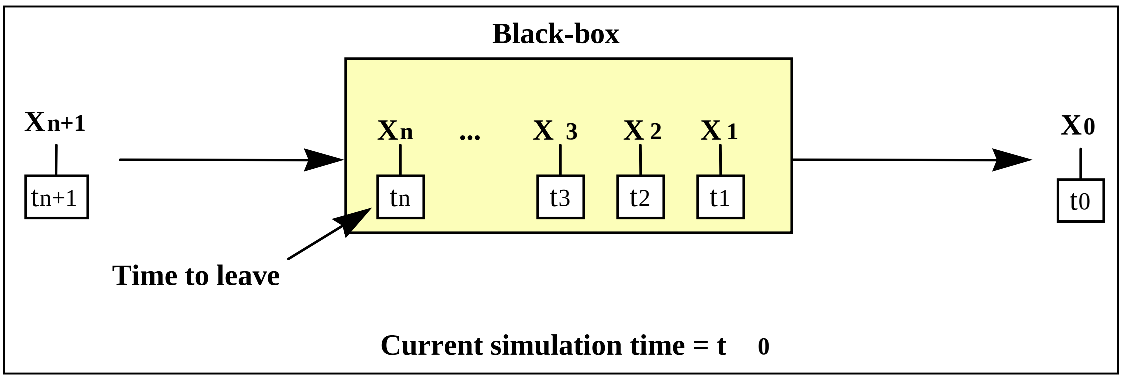


Figure 2. Black-box Modelling (Robinson, 1994)

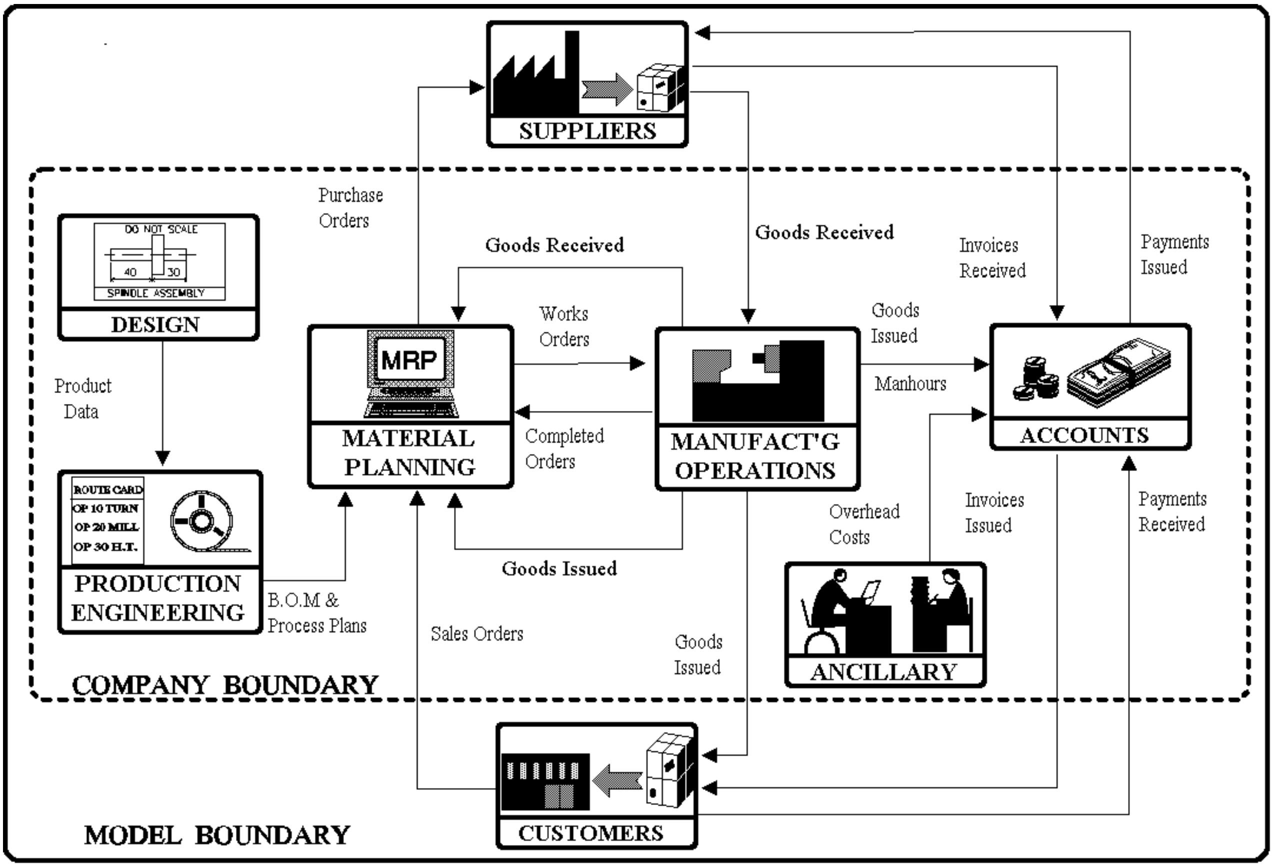


Figure 3: Whole Business Simulator (Love and Barton, 1996)

The DTI sponsored study (Hollocks, 1992) found that £300 million could be saved by British Industry per year if simulation was more widely used within the manufacturing sector. It would be interesting to find out how much could be saved and how many BPR projects could become successful if simulation models were developed and experimented with prior to changing business processes. Regardless of precise estimates, it is apparent that the more widespread use of simulation for business process modelling could increase the rate of success of business process re-engineering projects, which should then result in savings in resources and better service provided to customers.

## REFERENCES

Darnton, G., and M Darnton (1997). Business process analysis. International Thompson Business Press, London.

Davenport, T.H. and J.E. Short (1990) The new industrial engineering: information technology and business process redesign. Sloan Management Review 11-27.

Davenport, T.H. (1993) Process innovation: reengineering work through information technology. Harvard Business School Press, USA.

Earl, M.J. (1994) The new and the old of business process redesign. *Journal of Strategic Information Systems* 3(1) 5-22.

Ferrie, J. (1995) Business processes - a natural approach. ESRC Business Processes Resource Centre, University of Warwick, http:\\bprc.warwick.ac.uk\forum1.html.

Gladwin, B. and K. Tumay (1994) Modelling business processes with simulation tools. *Proceedings of the 1994 Winter Simulation Conference*, Ed. by Tew J.D., Manivannan S., Sadowski D.A. and A.F. Seila, SCS, 114-121.

Hammer, M. and J. Champy (1993) Reengineering the corporation. NY: Harper Collins Books, New York.

Harrison B.D. and Pratt M.D. (1993) A methodology for reengineering businesses. Planning Review 21(2) 6-11.

Hollocks, B. (1992) A well-kept secret: Simulation in manufacturing industry review. OR Insight 5(4) 12-17.

Jackson, B. (1996) Reengineering the sense of self: the manager and the management guru. *Journal of Management Studies* 33 .571-590.

Kettinge,r W.J., J.T.C. Teng, and S. Guha (1997) Business process change: a study of methodologies, techniques, and tools. MISQ Quarterly March 55-80.

Love, D. and J. Barton (1996) Evaluation of design decisions through CIM and simulation. Integrated Manufacturing Systems 7(4) 3-11.

Omrani, D. (1992) Business process reengineering: a business revolution. Management Services, October.

Pall, G.A. (1987) Quality Press Management. Prentice-Hall, Englewood Cliffs, New Jersey.

Paolucci, E., F. Bonci, and V. Russi (1997) Redesigning organisations through business process re-engineering and object-orientation. *Proceedings of the European Conference on Information Systems*, Cork, Ireland, 1997, 587-601.

Paul, R.J., V. Hlupic, and G. Giaglis (1998) Simulation modelling of business processes. *Accepted for UKAIS'98 - UK Academy of Information Systems Conference* Lincoln, UK, April 1998.

ProSci's 1997 Benchmarking Study - Best Practices in Business Process Reengineering and Process Design (1997), ProSci.

Robinson, S. (1994) Successful simulation: a practical approach to simulation projects. McGraw-Hill of Europe, Maidenhead, UK.

Saxena, K.B.C. (1996) Reengineering public administration in developing countries. Long Range Planning 29(5) 703-711.

Talwar, R. (1993) Business reengineering - a strategy – driven approach. Long Range Planning 26(6) 22-40.

Tumay, K. (1995) Business process simulation. *Proceedings of the WSC'95 - Winter Simulation Conference*, Washington DC, USA, Ed.by Alexopoulos A., Kang K., Lilegdon W.R. and Goldsman D., SCS, 55-60.

Wastell, G.W., White P. and Kawalek P. (1994) A methodology for business redesign: experience and issues. Journal of Strategic Information Systems 3(1) 5-22.

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## AUTHOR BIOGRAPHIES

**VLATKA HLUPIC** received a Dipl.Econ. and an M.Sc. in Information Systems from the University of Zagreb, and a Ph.D. in Information Systems at the London School of Economics, UK. She has published over 70 papers in journals and conference proceedings, mainly in the area of simulation modelling. She has consulting experience in the manufacturing, waste disposal and service industries. She is a Director of the Centre for Re-engineering Business Processes and a Senior Lecturer at Brunel University. Her current research interests are in simulation software evaluation, business process modelling and in simulation packages.

**STEWART ROBINSON** lectures in Operational Research and Systems at the Warwick Business School in the UK. He holds a BSc and PhD in Management Science from Lancaster University. Previously employed in simulation consultancy, he supported the use of simulation in companies throughout Europe and the rest of the world. His research interests are in finding ways to improve the use of simulation within industry and he is author of the book *Successful Simulation* (McGraw-Hill), a practical guide to simulation projects. Current work involves an investigation into the use of expert systems to represent a human decision maker in simulation models and developing an understanding of quality in relation to simulation studies.