BUSINESS PROCESS MODELLING USING DISCRETE-EVENT SIMULATION: CURRENT OPPORTUNITIES AND FUTURE CHALLENGES

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ABSTRACT

Competitive pressures and global business trends urge many organisations to radically change business processes. Although this 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 to be used for business process modelling and discusses its main challenges and opportunities. Following a discussion on business process modelling methods and tools, the use of simulation modelling for evaluating alternative business process arrangements is investigated. Two examples of simulation models representing business processes are presented and discussed. Future trends and challenges in business process simulation are discussed and conclusions are drawn.

1. INTRODUCTION

The apparent increase in 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 the military [37]. Another emerging application area of simulation is Business Process Re-engineering (BPR). In mid 1990's, BPR has become one of the most popular topics in organisational management creating new ways of doing business [40]. This management concept relates to the fundamental rethinking and radical redesign of an entire business system in order to achieve significant improvements in performance of the company. Although there are some arguments that BPR might be dated, companies are always changing business processes, and in this paper we use the term "BPR" to represent business process change, either radical or incremental.

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 [24]. However, regardless of the number of companies involved in re-engineering, the rate of failure in re-engineering projects is over 50% [15]. 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 the inability to recognise the dynamic nature of the processes.

Various 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 [2; 12; 31; 40]. Mistakes brought about by BPR can only be recognized 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.

While there is a plethora of tools available to support BPR efforts, simulation modelling in particular offers a great potential in modelling and analysing business processes. For example, simulation models can dynamically model different samples of parameter values such as arrival rates or service intervals, which can help 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 focuses on the application 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. Several examples of using simulation for business process modelling are also presented. The paper concludes with a discussion of emerging trends and key challenges in this area.

2. BUSINESS PROCESSES

There is no clear and agreed definition of a "business process" available in the literature. For example, Hammer and Champy [15] define a process as "a set of activities that, taken together, produces a result of value to a customer", whilst Davenport and Short [7] define it as "a set of logically related tasks performed to achieve a defined business outcome". According to Davenport [6] a process is "an ordering of work activities across the place, with a beginning, an end, and clearly identified inputs and outputs".

Ferrie [10] defines processes as being "a definable set of activities which form a known starting-point". According to Omrani [29], a process is "a cycle of activities, which taken together achieve a business objective". Pall [30] defines 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. Saxena's [36] 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 [38] defines a process as "any sequence of pre-defined activities executed to achieve a pre-specified type or range of outcomes." Finally, Earl [8] defines 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".

The above definitions of business processes show that there is no consensus amongst the authors. Nevertheless, 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) [21]. Re-engineering a business process involves changes in people, the process' constituent activities and technology over time. As these changes usually result in different ways of executing activities and different interdependencies between people, activities, and technology, 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. BUSINESS PROCESS MODELLING METHODS AND TOOLS

The number of organisations engaged in Business Process Re-engineering (or change) activities is continuously increasing [14]. As a result of this, there is a multitude of approaches, methodologies, and techniques to support BPR efforts [13; 17; 3; 1; 16; 45]. Software applications for business process modelling are continuously being released on the software market [37], ranging from simple mapping tools (e.g. Microsoft Visio) to deterministic modelling tools (e.g. Microsoft Excel) to discrete event simulation (e.g. ProModel). A majority of software tools for business process modelling have an origin in process mapping tools [9] that provide the user with a static view of the processes being studied (e.g. drawing IDEF0 models in Microsoft Visio). They represent business processes by graphical symbols, where individual activities within the process are shown as a series of rectangles and arrows. 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 conduct "what if " analysis and show a dynamic change of business processes and evaluate the effects of stochastic events and random behaviour of resources which is possible by using simulation models of business processes [31; 40]. Simulation software tools are able to model dynamics of the processes such as the build up of queues and show it visually, which can then stimulate the identification of 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 [43].

In a survey of existing methodologies, tools, and techniques for business process change by Kettinger et al. [25] simulation is indeed mentioned as one of the modelling methods. However, the use of simulation for business process modelling does not seem to be widespread. Gladwin and Tumay [11] 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 evaluating alternative re-designed processes. These findings were corroborated by ProSci's 1997 Benchmarking Study [33]. This study analysed over 60 large international organisations who went through a BPR exercise, looking at 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. 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.

Another recent study on the role of simulation for supporting BPR (and other change management approaches) also concluded that simulation tools have a lot of potential in supporting BPR and similar approaches, but this is yet to be realised in practice [18].

From the above discussion, it appears then that the full potential of simulation modelling tools for business process change is yet to be discovered. However, it may also be that simulation modelling tools have some drawbacks that thwart their widespread organisational adoption. For example, Kettinger et al. [25] 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. This is in line with findings provided by [2] who studies the role of simulation for modelling manufacturing processes. In the next section we take a closer look at the (un)suitability of simulation for process modelling.

4. BUSINESS PROCESS MODELLING USING SIMULATION

Although there is an increasing number of business process simulation studies available in the literature [28; 39; 2; 35; 26], it is apparent from the above discussion that the potential of simulation for business process modelling has yet to be recognised within 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 improving these processes. In terms of the business environment, simulation models usually focus on the analysis of specific aspects of an organisation, such as manufacturing or finance. The following two sub-sections discuss the suitability of simulation for business process modelling and the process of business process simulation respectively.

4.1. Suitability of Simulation for Business Process Modelling

Simulation models can be regarded as problem understanding rather than problem solving tools. They provide quantitative information that can inform decision-making. 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 describes the entire experience of 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 continuous process improvement.

An important benefit is the fact that experiments with business models can be repeated, which enables the evaluation of the effects of single or multiple changes. Once the model is reset, another change can be implemented and its impact evaluated. This means, for example, that two systems can be compared under the same conditions and the realistic effect of change can be therefore established, which would not be possible in either real-life experiment or by using static models [32; 23; 34]. As changes are being done to the model, rather than to the real system, these changes are much cheaper, easier and safer than experimenting with the real system. Furthermore, simulation models can use both standard and non-standard statistical distributions allowing real data (collected in the system being modelled) to be used for experiments, which should result in more realistic results obtained from models [34].

It is apparent that the benefits of using simulation for business process modelling are numerous. Simulating the effects of redesigned processes before implementation improves the chances of getting the processes right at the first attempt. Animated or 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 change approval. Such models can also be used for marketing, communication and benchmarking purposes.

Models can be built at various levels of abstractions, as many simulation packages allow development of sub-models, which can be shown or hidden for communication purposes. Business process simulation could 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.

However, the benefits of using simulation for business process modelling come at a price. The modelling process is often lengthy due to the complexity of the modelling environment. Simulation projects can also be costly as professional simulation tools are expensive and models have to be build by well-paid simulation experts. This means that simulation is not always the best pick from a portfolio of business process modelling tools. We argue that simulation is more appropriate when more of the following conditions are met:

1. The business process is a stochastic nature – events that trigger activities occur stochastically.
2. There are complex interdependencies between the activities and resources in the process which lead to dynamic changes in the process.
3. The business process consists of a complex flows of activities, which can best be understood by visually depicting its dynamics.
4. Alternatives to change the business process are risky and costly, so the effects of change have to be measured accurately as possible.

4.2. The Process of Business Process Simulation

There are various ‘standard methodologies’ for developing business process simulation models. Most of these methodologies 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 [21]. Although these steps are sequential, they are usually carried out iteratively and incrementally in several individual steps are usually repeated until they produce a suitable outcome. The steps presented in figure 1 depict a general process, which bears of lot of similarity to standard methodologies, such as those provided by, for example, [21], [35], and [12].

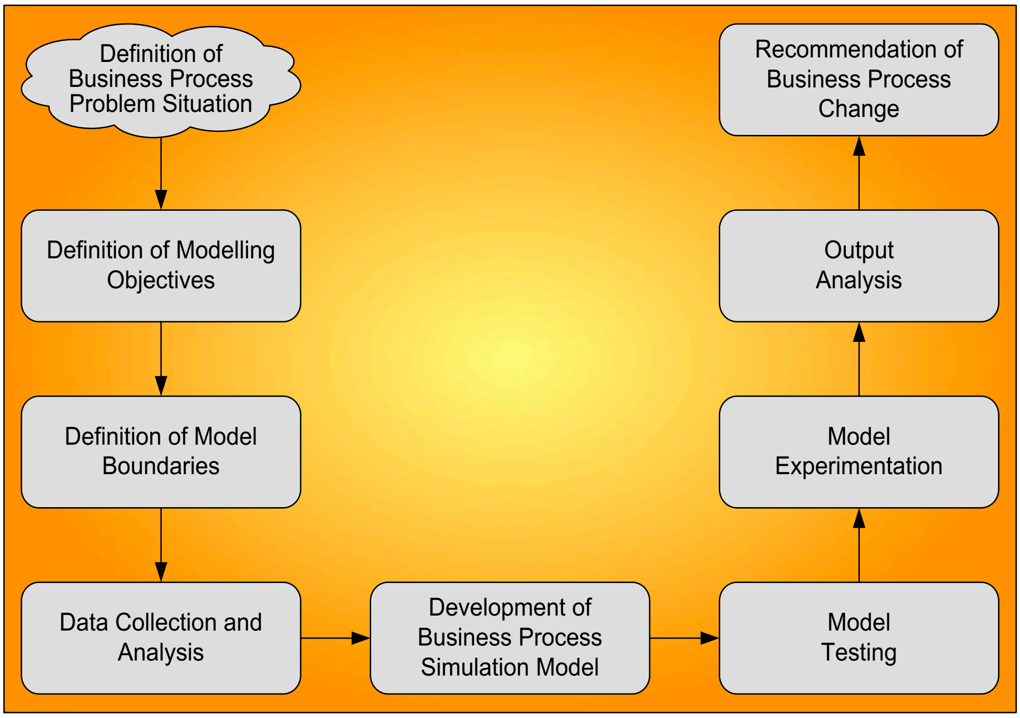

Figure 1. The process of business process simulation.

The process commences once the business process problem situation has been defined. The first step "Definition of Modelling Objectives" relates to determining what is the required outcome of the modelling efforts and which information should be provided by the model. For example, the objective of the modelling efforts might be to evaluate the effects of downsizing or allocating particular tasks within processes to different employees. In the second step "Definition of Model 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 (1) the importance of certain processes or a need to redesign inefficient processes, (2) the suitability of particular processes to be captured in a simulation model, and (3) available time and resources for the modelling effort.

In the next stage ("Data Collection and Analysis"), relevant 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 processes to be modelled, through observation of the existing processes and through studying the documentation about the processes. Collected data needs to be analysed using standard statistical procedures such as distribution fitting. The subsequent step "Development of Business Process Simulation Model" relates to a simulation model development using a simulation software package. This should be done through an iterative process where simple model is initially developed, which is then expanded and refined until acceptable model is obtained.

In the "Model Testing" step, after each iterative step in model development, "models in progress" should be thoroughly tested using as many model verification and validation techniques as necessary. Once no significant problems are discovered during thorough testing of simulation model, experimentation with model can commence ("Model Experimentation" step). Formal experimental design seems to be appropriate where there is 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 [5]. 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 could be 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 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. Statistical tests can be used to determine whether there are significant differences between key model output variables of different experiments. Finally, in the "Recommendations of Business Process Change" step, the simulation model output analysis is used as a basis for making recommendations regarding business processes change or improvement [21].

5. EXAMPLES OF BUSINESS PROCESS SIMULATION

To illustrate how simulation modelling can aid business process reengineering efforts, this section presents two case examples. We first describe a study at a hospital were a simulation model was used to enable incremental learning and exploration of possible process changes. Then we illustrate the use of simulation modelling to investigate the effects of implementing of new information technology on business processes and their performance. Both case situations met the four conditions regarding the suitability of using simulation modelling techniques, as presented in section 4.2. Both cases were executed by one of the authors in close cooperation with stakeholders from the organisations involved.

5.1 Example 1: Neurology Outpatients Department

The first example concerns a Neurology Outpatients Department (NOD) in a metropolitan hospital. This department was faced with increasing demands on their services, a more critical attitude on behalf of their patients, and a reduction of available monetary and medical resources. In response, the NOD management decided to investigate ways to change their business processes so that patients' visits could be carried out more efficiently. This were to be done through a simulation modelling project in which relevant existing and future processes were analyzed. A key project principle was that future business processes had to be based on current and future flows of patients. The project focused on the NOD itself and three function departments that jointly handled 91 percent of all function examinations for the NOD: Blood Lab, Radiology, and Clinical Neurophysiology.

The simulation model of the NOD included the working procedures of personnel concerned, such as physicians, desk personnel, secretaries, and nurses. The tasks they performed with regard to NOD patients were identified and defined in the model. A screenshot of the NOD simulation model (developed in SIMAN/Cinema) is depicted in figure 2.

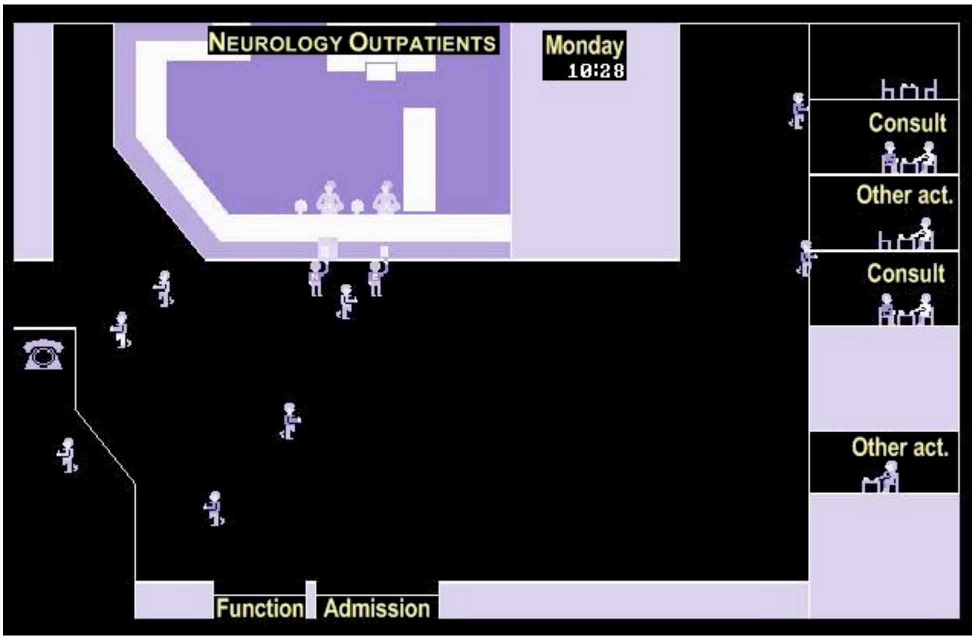

Figure 2. The simulation model of the NOD's business processes.

Apart from a patient's medical information that is stored in his/her medical record, the NOD uses other information such as appointment dates, required function examinations, treatment planning, or admission decisions to coordinate the flow of patients visiting the department. This coordination information is recorded on forms and given to the patients who then deliver the forms to the appropriate person or department. As a result, patients that visit the NOD are sent from pillar to post through the hospital. Essentially, patients function as a medium for the physicians, function departments, and the front desk to coordinate their tasks.

The simulation model was demonstrated during a workshop to NOD staff members. The staff members identified a number of possible business process changes, two of which were selected for further exploration based on feasibility and expected benefits:

1. *Option 1: Decentralised access to schedules.* This would enable NOD's front desk personnel to make appointments for patients with Radiology and Clinical Neurophysiology as well. Patients no longer needed to go to these departments themselves for making an appointment.

2. *Option 2: Decentralized access to schedules & Drawing blood at the front desk.* An analysis of the current situation with the simulation model showed long waiting times at the Blood Lab. NOD patients had to go there without an appointment and have their blood drawn together with patients from other hospital departments. The proposed additional process change would entail desk personnel to be trained to draw blood, so that NOD patients would not have to visit any other departments during their visit.

To determine the effects of the proposed process change options they were included into the simulation model. The effects were measured by looking at the average patient visit time to the NOD. Table 1 shows the results. At first glance, the improvements in options 1 and 2 do not appear to be very dramatic. This is due to the fact that the greatest component of the visiting time is the time spent in the waiting room and the consulting time. These times are not affected by the process changes options.

Option	Average visit time (min)	Relative improvement
Current situation	51.4	-
Option 1	49.0	4.8 %
Option 2	45.8	10.9 %
Option 3	42.4	17.5 %

Table 1 Average visiting time in minutes for various reorganization options.

The improvements from the second option are much more substantial than those from the first one. After studying the results, a third option was added to the model: it turned out that after implementing option 2 in the model, patients would queue up at the front desk when all physicians were giving consultations at the same time. However, on some days only one or two physicians gave consultations. Option 3 therefore concerned an extension to option 2 by spreading the physicians' consultation hours evenly over the week. As can be seen, this option yielded the best results. A key advantage of the simulation model in this situation was that unforeseen effects of process changes were recognized and handled before actual implementation took place.

5.2 Example 2: Department of Unemployment Benefits

The Department of Unemployment Benefits (DUB) is a ministerial department that manages unemployment payments to civil servants (clients). It handles applications for benefits and determines the amounts of monthly benefits. Each month, the DUB processes some 10,000 documents and oral requests. It employs 80 people in 5 departments: Regulations (for calculating new and current benefits), Special cases (for special calculations and requests by telephone), Verification (for checking all calculations), Archives (for the storage of documents and the messenger rounds, i.e., transporting documents between departments) and the Mail room (for sorting and forwarding incoming and outgoing mail).

Governmental reorganizations are expected to lead to a disproportionate increase in the number of benefit applications. In addition, the DUB's current performance is not satisfactory. It appears that 2.5% of current benefits are not processed on time, resulting in late payments. In addition, some 500 incorrect payments are made, because changes in client information are not processed in time. As a result, the DUB's service level is below 90%. The service level is defined as the percentage of correct and timely benefit payments for which the DUB had the required information available on time. Striving for a 99% service level, the DUB's management decided to change the way the business processes are executed.

To investigate the effect of possible changes, a simulation model of the DUB's working processes was created in SIMAN/Cinema. This model included information such as procedures to process different types of documents, data on the arrival of documents, and employee work schedules. A screenshot of the DUB simulation model is depicted in figure 3.

Figure 3. The simulation model of the DUB's business processes.

Using the simulation model, an analysis of the current situation at the DUB revealed that the workload in the departments varied a lot during the course of a day. Moreover, the variation was related to the schedule of the messenger rounds that bring documents and other information from one department to the next. It turned out that sometimes half a department was sitting idle while there was work for them waiting in another department – it just had to be moved. Based on this insight, the management decided to investigate two options to improve the DUB's performance (i.e.the service level):

1. *Option 1: Additional messenger rounds.* DUB employees argued that more rounds were needed to accelerate the transport of documents. Based on available capacity, two additional messenger rounds were implemented in the model.
2. *Option 2: Electronic Document Handling (EDH).* DUB management argued that work buffers between departments could be eliminated if all documents were handled electronically. If one employee finished his/her task on the documents, the EDH system would automatically route it to the appropriate next employee. At the Mail room, all documents would be scanned and stored in a central database. Since they would no longer have to do their messenger rounds, the Archives employees would assist the Mail

room in scanning incoming and archived documents.

Both options were implemented in the different versions of the simulation model. The effects were measured by looking at the number of documents that were processed too late and the resulting service level. The results are shown in table 2.

Option	Documents processed too late	Service level
Current situation	632	89.5 %
Option 1	476	92.0 %
Option 2	78	98.7 %

Table 2 Service levels for the various options.

The results show that an increase in the number of messenger rounds does not result in satisfactory improvements of the service level: the service level is still far from the desired 99%. Moreover, the management considered almost 500 incorrect or late payments on a monthly basis unacceptable. Yet, the EDH solution provided a substantial improvement. The required service level is practically achieved. The management decided to opt for this system and initiate a call for proposals from potential vendors. The results were also used to negotiate job description changes with all employees involved. The value of the simulation modelling efforts in this project concerned the assessment of current performance levels and quantifying possible improvement through changes in working procedures and IT investments.

6. CURRENT TRENDS TO ADDRESS FUTURE CHALLENGES OF BUSINESS PROCESS SIMULATION

This paper argues that business process simulation has considerable potential and that it can provide substantial benefits to companies planning to change business processes. The two case studies presented above illustrate this point by showing the value of investigating the effects of changes to business processes using simulation models rather than implementing them into the real processes straight away. Although the potential of business process simulation is yet to be widely recognised by the business community, and developing simulation models might be time consuming and costly, the many benefits are evident. For example, simulation models are able to capture dynamics, variability, complexity and interconnectivity of business processes allowing "what if" analysis to be performed before changes in the real system are implemented. From a managerial perspective, benefits of using process simulation include fostering creativity, creating knowledge and understanding, supporting visualisation and communication and building consensus [35].

The future of business process simulation presents many challenges and opportunities for further research and development. Below of number of these will be elaborated. The *first* key challenge concerns the *effective and efficient involvement of a large number of stakeholders and subject matter experts in simulation modelling activities*. As business situations and problems are becoming more complex, the time available to deliver solutions is more limited, and the dynamics of the business process problems are changing more quickly, there is a growing need to involve more people in the simulation modelling process. In addition, broader participation may foster broader acceptance of the outcomes of a business process re-design effort. However, the need for broader involvement in a shorter period of time implies that the traditional way of conducting simulation-based business process modelling studies may not be sufficient anymore. One way to address this challenge is by making more extensive use of collaborative modelling methods and tools to support all phases of the simulation modelling process (for some initial experiences see e.g. 4; 27; 19). This area itself presents researchers and practitioners with a number of challenges, including:

- Integrating collaboration and simulation tools, e.g. feeding data estimates obtained using collaboration tools into simulation models.
- Dealing with the complexity of the roles and responsibilities involved, e.g. analyst – project manager – process manager – subject matter expert – group facilitator.
- Dealing with increasing demands on managers' time and expertise. Managers not only need to understand the strengths and weaknesses of

simulation methods. They also need to understand group dynamics, attend simulation workshops and learn how to have their workforce successfully adopt both collaboration and simulation methods and tools.

- Making the most of the available collaboration and simulation tools. The usefulness of both types of tools is bound by the quality of the process in which they are used. Using collaboration tools, it becomes more critical to involve right people at the right time in the redesign process. In situations with broad stakeholder participation, special requirements are placed on tools and techniques, e.g. the trade-off between simple, easy-to-use tools vs. more sophisticated yet complex tools.
- Facilitating effective involvement when stakeholders and subject matter experts are not co-located. Engaging distributed participants in collaborative simulation activities not only makes effective collaboration among participants harder to achieve, it also introduces a need for distributed simulation models.

The *second* key challenge concerns finding ways to *decrease model building time*. The authors' experience shows that decision makers and managers want the outcomes of a simulation study 'immediately', i.e. sooner than they can currently be delivered. Organisations usually cannot wait a couple of weeks or months for the results of a simulation study while their market position is deteriorating. Further research in automating and speeding the modelling process using reusable simulation modelling building blocks could address this challenge [41]. Building blocks represent small simulation models that symbolize one element of a system. When the building blocks are combined, they form a modular simulation model. For example, passenger flows in an airport could be modelled using building blocks that represent check-in desks, security check points, gates, and waiting areas. The advantages of such an approach include (see e.g. 41; 42; 44):

- Faster model development and model modification as models can be 'snapped' together using sub-models.
- Higher model quality because validated building blocks are used.

- Easier model verification as recognizable building blocks can be used.
- Better fit between model and problem domain as dedicated building blocks can be used.
- Opportunities for re-using building blocks to develop new models or extending them to obtain extra functionality.

A *third* and final challenge concerns *creating and enhancing management awareness about benefits and pitfalls of simulation modelling*. A number of studies have shown that management awareness of simulation benefits is rather low [20]. Although much research is carried out in increasing the efficiency of simulation modeling tools and methods, the issue of management awareness presents perhaps the major obstacle for wider use of simulation for business process modelling. It is our believe that the ongoing efforts described above to facilitate broader involvement and to reduce model building time will ultimately assist management to more easily recognize and reap the benefits of business process simulation.

7. SUMMARY AND CONCLUSIONS

This paper investigated the application 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 use of simulation modelling for evaluating alternative business process strategies was investigated, and two examples of business process simulation were presented. A summary discussion on current trends to address future challenges of business process simulation has also been provided.

It is apparent that simulation can be an effective 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 or too dangerous to experiment with the real business processes especially if business process change involves 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 increasing this understanding.

Already a decade ago, the DTI sponsored study [22] found that £300 million could be saved by the 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 change of business processes. Regardless of precise estimations, we argue that a more widespread use of simulation for business process modelling can increase the rate of success of business process re-engineering/change projects, which should then result in savings in resources and better service provided to customers within shorter timescales.

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