Business Process Management and Discrete Event Simulation: A Tool Survey

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Abstract

Business process management is one of the most cost-effective and rewarding ideas to come along in years. Many different techniques can be used for modelling and managing business processes in order to give an understanding of possible scenarios for improvement. In order to realize the expected impacts of business process change, most of companies use simple accounting techniques (Activity Based Costing Analysis or Return on Investment) or static process modelling techniques, which do not have the advantage of capturing the dynamic characteristic of business processes. Discrete event simulation modelling of business processes creates added value in understanding, analyzing and designing processes by introducing dynamic aspects.

The survey of the literature in this domain provides a list of reasons for the introduction of simulation modelling into process management. This paper focuses on a process of simulation features of Business Process Management (BPM) tools evaluation. The paper presents discrete event simulation (DES) in the context of BPM projects. An approach that could help managers in the selection of business process simulation tools is proposed. Two simulation tools (ARIS Simulation and IBM WebSphere Modeler) that are relevant for BPM field are evaluated. The results of the comparison and evaluation are discussed and the recommendations for further research are formulated.

Keywords: Business process management, Discrete-event simulation, ARIS, IBM WebSphere

1 Introduction

Business process management (BPM) enables the design, analysis, simulation, optimization, automation and diagnosis of business processes by separating process logic from the applications that run them; managing relationships among process participants; integrating internal and external process resources and monitoring process performance [1,2]. As a precursor to business process management, methods and tools to model and design processes are needed for the analysis of existing processes and for generation of alternative or changed processes.

Simulation of business processes creates added value in understanding, analyzing and designing processes by introducing dynamic aspects. Computer based simulation models of business processes can help overcome the inherent complexities of studying and analyzing organizations and therefore contribute to a higher level of understanding and designing organizational structures [3]. Since simulation approximates reality, it also permits the inclusion of uncertainty and variability into the forecasts of process performance. According to the literature, simulation is positioned as a mean to evaluate the impact of process changes and new processes in a model environment through the creation of "what-if" scenarios.

However, it is only recently that dynamic modelling, in particular Discrete Event Simulation (DES), has been considered an essential component of business process management projects. Kettinger *et al.* [4] mention simulation as one of the modelling methods in their survey on business process modelling methods. Because of the use of DES in the context of business process reengineering and of other process-based change projects, it is also referred to as business process simulation – BPS [5]. Serrano and Hengst [6] consider business process simulation a modelling technique that is very popular amongst business process practitioners.

Two main categories of software tools that may be applicable for business process simulation are: general purpose discrete event simulation (DES) tools and business process management (BPM) tools [7]. DES is a field that began to develop in 1957 by the creation

of the General Simulation Program (GPS) and over the history, a plethora of DES software packages and many successful applications have been reported. BPM tools integrate different methods to cover various aspects of the business system, such as: organisational structure of the system, internal behaviour aspects of the system, business policy and strategy, information and knowledge management. The results of surveys from business practice have shown the existence of a large potential market requiring the improvement of BPM tools with the components for dynamic modelling and measuring the performance of the processes. As a result of this, consultants and BPM software tools vendors developed simulation modelling features to support this.

This paper examines how dynamic modelling capabilities are significantly expanding the power of BPM tools. The goal of the paper is to compare and discuss the simulation features of BPM tools: ARIS Simulation and IBM WebSphere Modeler. The most important simulation capabilities of selected BPM tools are discussed and evaluated to provide insights in the advantages and disadvantages of each tool. The paper is structured as follows: Section 2 describes the application of discrete event simulation in business process management projects. Simulation features of BPM tools are presented in Section 3. A comparison and evaluation of simulation features is presented in Section 4. Section 5 presents some general conclusions and future work directions.

2 Using DES within a Business Process Management Approach

This section focuses on typical business motivations for the use of DES in an attempt to analyze and define its suitability to the range of BPM projects.

2.1 Applicability of DES to Business Process Management

Historically, DES has been used to analyze workflow systems [8], operations management, supply chain management and design [9,10], but recently it is being used in business process modelling [11] and organizational modelling [12].

The survey of the literature in this domain provides a list of reasons for the introduction of simulation modelling into process management. Amongst the most relevant are [13,14,15,16]: simulation allows for the modelling of process dynamics and supports the creation of dynamic models of organisational processes and information systems, the influence of random variables on process development can be investigated, re-engineering effects can be anticipated in a quantitative way - quantitative process metrics that can be addressed include costs, cycle time, serviceability and resource utilisation. Furthermore, process visualisation and animation are provided, allowing multidisciplinary team members to understand the model and communicate about it and facilitating communication between clients and an analyst and simulation modelling can be increasingly used by those who have little or no simulation background or experience.

One of the major goals of Business Process Management is to realize continuous process improvement and business activity monitoring (BAM). Thus, BPM vendors are offering greater capabilities in this area. Almost all vendors offer at least some sort of administrative console with metrics and reporting capabilities. Other vendors specialize in process monitoring and offer enhanced analysis functionality. Through reports and analysis, companies can take steps towards process optimization. In terms of BAM, simulation can be useful at the process design and monitoring stages, though not in real time.

Recent research of the role of DES in the context of Web services management shows that it may be used for the development of real-time control policies to manage process performance [17]. This study suggests that real-time simulation may be a potentially effective approach in the management of dynamic business process networks of the future.

2.2 The Role of DES in Business Practice

DES is being utilised to assist in the management of change in a variety of projects and the survey of the literature in this domain provides a short list of recent case studies.

A case study of modelling and automating business processes of a medium-sized bank introducing Internet technologies (intranet, workflow management system, Lotus Domino) was described in the paper by Nikolaidou, Anagnostopoulos, and Tsalgatidou [18]. A simulation modelling is used to study the personnel capacity utilisation in a maintenance department [19]. The results of the simulation show that the best utilisation of the personnel and the best throughput time of maintenance work orders is obtained if the personnel

is allowed to function across the borders of their department. Greasley [20] presents a case study of the use of business process simulation within the context of a business process reengineering approach to change the custody-of-prisoner process at a police force.

Hlupic and Bosilj Vuksic [21] present a BPS model of a telephony system of a large multinational company that has been used for determining business processes that needed to be radically changed. Kokin and Lau [22] describe a restructuring effort of a Hong Kong-based company which provides technical support services in office equipment, computer and system products. Faced with many process improvement opportunities, a simulation approach is used to explore the different options and to evaluate the results for restructuring the existing call centres.

Simulation is commonly used in supply chain analysis due its strength in predicting system variation and interdependencies. Mahendrawathi and MacCharty [23] present findings from a simulation study investigating the impact of product variety, supply lead-time and demand uncertainty on a multinational corporation supply chain performance. The simulation focuses on the upstream activities of production planning, inbound supply and manufacturing.

Weyland and Engiles [24] explored how workflow performance could be improved through an approach that aligned the network architecture with an organization's business processes. According to the authors simulation models can uncover problems with business process flow, and can be used to improve or even optimize the process flow "network." Optimization of such a network, which can be accomplished through simulation, can provide a sound basis for the design of Web services that will successfully support the organization's business processes. Madhusudan and Son [17] propose a simulation-based framework to guide scheduling of composite service execution. Comparison of the look-ahead simulation for different scheduling policies with the current execution state provides guidelines for service execution in order to cope with system volatility.

The results of surveys from business practice have shown that DES is very often used in BPM projects despite of different projects' scope, objectives and goals. The common characteristic of the examples listed above is the implementation of general purpose DES tools or languages, such as: Arena, Service Model, SIMUL8 and GPSS. Obviously, the issues relating to simulation features of BPM tools and their implementation in business practice have not been addressed simultaneously in the literature to date. Similar thesis could be found in 'The 2005 Enterprise Architecture, Process Modelling & Simulation Tools Report' [25]. The authors stress the fact that although many process modelling tools provide simulation engines, only a few of their customers actually use the simulation capabilities. This study aim to fill part of this gap by addressing the following research question:

Do simulation features of business process management tools meet discrete event simulation requirements?

To address the research question an empirical study has been conducted. The purpose of the empirical study was to provide insights on the simulation characteristics of BPM tools by comparing and evaluating two software packages.

3 Simulation Features of BPM Tools

Many authors have described desirable software features for the selection of DES software. This section explores DES tools characteristics and defines their evaluation criteria.

3.1 Characteristics of DES Tools

An important aspect of DES tools is its ability to capture the dynamic behaviour of a process. There are two aspects of dynamic systems that need to be addressed: variability and interdependence [20]. Most business systems contain variability in the demand on the system and in durations of processes. Most systems contain a number of independent decision points that affect the overall performance of the system. According to Oakshot [26] a range of features desired from a simulation tool are: modelling flexibility, ease of use, animation, general simulation functions (e.g. warm-up period, multiple runs), statistical functions, interface with other software, product help and support, price and expandability.

Pidd [27] identified the general principles for selecting discrete simulation software by dividing these principles into three main groups. The first one is focused on computer programming, covering the field of logical machines, machine code, assembly languages, compilers and interpreters. The second group of principles analyses different simulation executive ap-

proaches, model logic, distribution sampling, random number generation and report generation. The last group of principles examines a range of factors which should be considered when appraising DES software, such as: the type of application, the expectation for end-use, knowledge, computing policy and user support.

Law and Kelton [8] identified the following groups of features: general capabilities (e.g. modelling flexibility and ease of use), hardware and software considerations, animation, statistical capabilities (including random number generator, probability distributions, replications and warm-up period), output reports, customer support and documentation.

Hlupic, Paul and Irani [28] defined general criteria for the evaluation of simulation packages, which can be applied to the evaluation of any simulation package, regardless of its application area. The criteria are "naturally" classified according to their nature into 13 groups: general modelling features, visual aspects, coding aspects, efficiency, modelling assistance, testability, software compatibility, model input/output, experimentation facilities, statistical facilities, user support, financial and technical features and pedigree of the software.

3.2 Evaluation Criteria

However, it would not be realistic to expect particular BPM software to satisfy all criteria for general purpose discrete event simulation (DES) tools defined by the authors and listed above. Therefore, the most important simulation features are selected to be compared within this research. When evaluating simulation features of BPM tools, the modelling, simulation, input/output issues and reporting capabilities are important [7].

The aim of *modelling criteria* is to evaluate how well and precise a business process can be represented by using simulation features. Most of these criteria relate to modelling aspects such as the representativeness of models (models' transparency, resource and data perspective, level of detail and suitability for communication), efficiency and the formal semantics. Representativeness is expressed by the capability of the software to model a variety of complex systems. Efficiency is the characteristic which can save time needed for modelling and improve the quality of modelling such as model reusability, reliability and time scale for model building. Formal semantics provide a precise description of the behaviour of the modelled processes. There are also some criteria that evaluate the level of experience and education required from the user, and examine how easy it is to learn and use the tool. Model building should be easy to allow users to be involved in the modelling of their processes.

The purpose of the *simulation features* is to evaluate in which way a simulation can be performed and which attributes and parameters can be used. The simulation features evaluation criteria are: visual aspects, statistical facilities, testability and experimentation facilities. Visual aspects of simulation models and animation of simulation are very important characteristics of simulation software. These criteria evaluate, for example, whether it is possible to perform animation of simulation experiments, the types of animation provided by the package, expressiveness and quality of graphics. Due to the randomness that is present in the majority of simulation models, good statistical facilities are very important. Most tools provide predefined methods for statistical fit and data analysis. Some tools also feature specific interfaces for integrating with advanced statistical analysis packages, such as Stat Fit, Expert Fit or MINITAB. Testability comprises criteria that examine which facilities for model verification are provided by the package. Experimentation facilities are required for improving the quality of simulation results and for speeding up the process of designing experiments and of the experimentation itself. With the use of scenarios the effects of changes can be predicted and investigated.

The category *input/output issues* is "naturally" grouped into three subcategories, according to their character: analysis capabilities, input capabilities and output capabilities. Analysis features provide the what-if-analysis (different scenarios comparison), optimization and conclusion-making support which facilitates the interpretation of the simulation results, such as: the identification of trends, the slicing and dicing of data and the tracking of the cause of specific outcomes. Simulation should provide statistically proper input data and outputs (results) and it should be clear how these results are calculated. Input and output criteria investigate how the user can present the data to the package and the type and quality of output reports provided by the package. Most tools provide interfaces, enabling them to import data from a range of software packages and databases. Some tools offer the ability to read data in real-time from

operational systems and databases for use by a simulation engine. Finally, most tools provide the export of data captured during simulation to Excel and other tools in order to take advantage of their analysis capabilities.

Capabilities for the *capture and reporting* of simulated metrics are very important for business analysts and users of BPM tools and therefore are considered in this research. These capabilities vary among tools. Some tools provide various pre-defined analytic reports, which can be customized by users to suit their own specific needs. A range of reports is provided: from standard text-based reports to highly graphical reports. Moreover, some products enable real-time plotting and graphing features that are useful for dynamic analysis of process behaviour.

4 Comparison of Simulation Features

Two BPM tools are selected for the evaluation of the simulation functionality: ARIS Simulation (IDS Scheer) and WebSphere Business Modeler (IBM).

4.1 ARIS

ARIS Business Simulation relies on the client/server architecture of the ARIS Platform from IDS Scheer. This means that customers are able to simulate even complex business processes, as all the information in the central ARIS Repository is available to them. Customers can not only realistically simulate process hierarchies and interlinked business processes; organizational structures and other resources involved in the process are also taken into account. ARIS Business Simulation also enables a detailed analysis of both the existing and planned structural and procedural processes within companies and organizations. With the animation mode directly in the model, process analysis is particularly transparent. The simulated process flow can therefore be visibly tracked.

In order to prepare results, numerous statistics and charts are available, which also enable monitoring of throughput times and waiting times at specific points in the process, for example. ARIS Business Simulation works with ARIS standard models and is being extended to include other modelling standards, such as BPMN (Business Process Modelling Notation). ARIS Business Simulation works with all web-based products of the ARIS Platform, such as ARIS SOA Architect, ARIS Business Optimizer and ARIS IT Architect.

4.2 WebSphere Business Modeler

WebSphere Business Modeler is built on the *Eclipse development platform. It* gives business professionals the tools they need to design, simulate, improve and communicate complex *business processes*. Process simulation using WebSphere Business Modeler enables the simultaneous viewing and examination of all cases in a virtual work environment. Process simulation also provides the ability to vary process input volume over time by adjusting resources and current allocations. Simulation output provides detailed information regarding resource utilization levels, as well as cost and cycle time calculations.

WebSphere Business Modeler supports the following key simulation activities: graphical modelling of current and potential business processes, performing simulations to see how business processes will perform under different "what if" scenarios and environmental conditions, analyzing the simulation results to determine how to correct problem areas in process models, generating reports from simulation results using a wide variety of predefined report templates, or creating new reports.

4.3 Methodology and Analysis

According to a pre-defined set of evaluation criteria, ARIS Simulation and WebSphere Business Modeler are examined. Since the most respected evaluations of BPM tools are performed by Gartner Group, the tools compared in the research were taken from the top-ranking ones according to the Gartner 2006 report [29]. The tools were donated to the authors of the paper for educational purposes and scientific research.

A mark on a scale ranging from bad (-) and good (+/-) to excellent (+) is assigned to the simulation features of BPM tools according to the evaluation criteria defined and discussed in Section 3.2. The evaluation criteria of simulation features and the results of survey are presented in Table 1.

ARIS Simulation enables modelling and analysis options to provide insight into the dynamic interaction of the various processes modelled in eEPC (Extended Event Process Chain) diagrams. The simulation relies on the semantics of eEPCs. This is an informal modelling language which has been implemented in the ARIS Toolset. Due to the informal language, model verification is not supported by the tool. The models can be conveniently designed, has functional

SIMULATION FEATURES	ARIS SIMULATOR	WEBSPHERE BUSINESS MODELER
Modelling		
representativeness	++	++
efficiency	-/+	++
formal semantics	-/+	-/+
easy it is to learn	-/+	++
Simulation		
visual aspects	-/+	++
statistical facilities	-/+	++
testability	--	-/+
experimentation facilities	++	++
Input/Output		
analysis capabilities	-/+	++
input capabilities	++	++
output capabilities	++	++
Capture/Reporting		
analytic reports	++	++
real-time utilization, analysis and reporting	--	-/+

Table 1: **Evaluation of the features of BPM tools**

use of symbols and colours for different model elements.

ARIS's animation features allow users to (visually) determine first results and tendencies during the simulation itself. Visual changes to individual objects during the simulation may immediately indicate whether or not process branches are ever run through. The animation of objects and their attributes provides more detailed information about the state of individual objects, indicating, for example, the number of times a function is carried out at a certain point in time.

The following data can be determined by simulation: executability of the process (process weak points, resource bottlenecks), process duration that considers available resources for this process and other resources, execution frequency of a process within a given period, use of resources (employees, organizational units) by certain processes, wait times of the processes and localization of the process weak points.

With the simulation of target processes, the actual effect of planned restructuring can be forecasted and compared. ARIS Simulation does not support real-time analysis and reporting, but IDS Scheer's Solutions Groups can build such an interface.

The output format is a set of Excel spreadsheets. ARIS generates cumulative and detailed statistics of simulations and process efficiencies, and the statistics can be displayed in the form of charts, tables, and other diagram formats. Users can also export simulation results and statistics to Excel for further analysis, formatting, and publishing. The simulation engine produces various statistics from each simulation run that can be taken into statistical analysis tools like MINITAB. A good interface with other ARIS tools is developed, e.g., ARIS Process Performance Manager and ARIS Business Optimizer.

WebSphere Business Modeler offers a flexible, visual-modeling environment that is enhanced by the ability to colour-code elements according to role, classification or organization units. WebSphere Business Modeler also includes a "swimlane" view that is used to display a model according to role, resource and organization unit. The simulation relies on the semantics of Business Process Modelling Notation (BPMN) as a standardized graphical notation for drawing business processes in a workflow.

WebSphere Business Modeler supports extensive simulation capabilities, including: "what-if" scenarios, random, probability-based, or data-driven simulation modes, cost and time parameterization of activities and resources, built-in distribution functions, business artefact creation, expression evaluation and subsequent data based routing. Selected variables can be modified during simulation. During the simulation run, it animates the business flow execution. The immediate results are displayed in a separate view, and they are reported based on different categories, such as process, task, or connection. The results can be viewed, printed, and analyzed using a large number of custom and template reports.

Analytic Capabilities provide information on the results of one or more process simulations. Dynamic analysis reflects not only the underlying process model and other model elements that are used in simulations, but also the simulation results based on attributes specified for a particular simulation profile. There are more than twenty types of dynamic analysis, such as: activity cost analysis, process instance resource allocation analysis, process cost analysis and Processes cost comparison analysis.

WebSphere Business Modeler animates the flows in a step-by-step simulation allowing real-time data utilization. There is also a linkage between Business

Modeler and the WebSphere Business Monitor (a separate IBM product) to retrieve actual analysis information for use as part of a simulation. To support large simulations, Business Modeler includes usability and performance features that allow users to obtain simulation results quickly and store them in a relational database.

4.4 Discussion

According to the authors' opinion, evaluation criteria of simulation features listed in these guidelines represent an evaluation framework that can be used for BPM tool selection by potential buyers. The simulation features were selected according to their importance, but also based on the requirement of business practitioners and non-technical users to understand significance and functionality of the proposed features. The evaluation of these criteria is a result of authors' practical experience and survey of literature.

Generally, the results of research show that modelling capabilities are well supported, especially representativeness, efficiency and easy to learn. Simulation capabilities vary amongst products, but both tools support experimentation, visualisation and provide statistical facilities, while testability is purely supported because of the lack of semantics. Experimentation and statistical facilities are aligned to the level of users' knowledge about these features and their ability to use them. Input, output and analysis capabilities are well supported, as well as capture and reporting capabilities, while the only one exception is the real time date utilization and analysis.

According to the results of evaluation, the research question should be answered positively. It is evident from the above discussion that simulation features of business process management tools meet the majority of discrete event simulation requirements. However, their application in BPM projects is still very rare. The reason could be found in the lack of knowledge about simulation modelling. The experiences from business practice showed that BPS software should be usable by people with business knowledge, but little knowledge of simulation modelling. To meet this requirement, vendors of BPS tools made them user-friendly, easy to use, flexible, and targeted at not-technical business practitioners. Because of these characteristics, BPS tools are usually less appropriate for performing complex, detailed modelling. On the other hands, individuals experienced enough to do good simulations often prefer more sophisticated simulation tools. Consequently, the authors plan to explore these issues through further research.

5 Conclusion

In this paper a suitability of two BPM tools for discrete-event simulation is considered and analyzed. The tools have been evaluated on their modelling capabilities, simulation capabilities, input/output issues and capabilities for reporting. Both BPM tools showed very good simulation performances, as well as some disadvantages on their simulation capabilities and capture/reporting issues. A review of BPM tools and their simulation characteristics resulted in the framework suggested by the authors to be used in a process of evaluation of such tools. At present, its' development is not completed, and in order to verify and validate the proposed framework the authors intend to continue this research.

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