

TOWARDS A FLEXIBLE BUSINESS PROCESS MODELING AND SIMULATION ENVIRONMENT

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ABSTRACT

Business process is crucial to the success of any business. Business process modeling enables a common understanding and analysis of a business process, and simulation is an effective way to diagnose and evaluate complex business processes. There are lots of software tools in market for business process modeling and simulation, however, a common issue for these tools is the conflict between usability and flexibility. The improvement of usability often means the reduction of flexibility. This paper introduces an IBM asset named Supply Chain Process Modeler (SCPM), which aims at providing a tailored business process modeling and simulation environment for business users. SCPM tries to achieve a better trade-off between usability and flexibility with two major efforts, a process repository for process modeling, and a flexible environment for process simulation. A case study from real consulting practice is also included to illustrate how SCPM works for business process simulation.

1 INTRODUCTION

There is no doubt that business process plays a very important role in running a business. A healthy business process is the foundation of the success of an organization. The realization of all strategic objectives has to rely on business processes to achieve. Based on the result of a recent CIO survey, "streamline or optimize business processes" is the top business priority of executives (see Figure 1). In order to achieve process excellence, people carry on various process improvement initiatives, such as business process reengineering (BPR) and business process management (BPM), which have become the hottest terms nowadays.

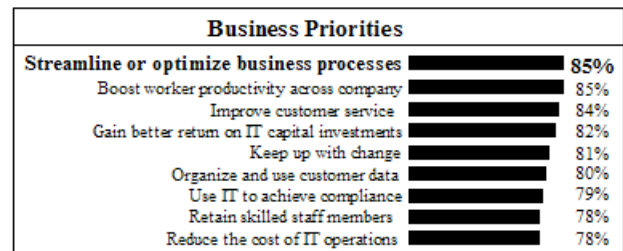


Figure 1: CIO business priorities (InformationWeek 2004)

No matter which process improvement initiative people want to conduct, they have to understand the business processes and perform necessary analyses to design or redesign the processes. Business process modeling enables a common understanding and analysis of a business process, while computer simulation is an effective technology to diagnose business processes, especially when complexity and scope become issues. Often, as existing processes are modeled and simulated, complex relationships and behaviors are exposed and evaluated.

There are a lot of commercial-off-the-shell (COTS) tools available for business process modeling and simulation, however, despite the increasingly enhanced functionalities, there are still some obstacles in widely using these tools. The common issue is the conflict between usability and flexibility. Typically, the more flexible functionalities a tool intends to provide, the more difficult to use the tool will be. Moreover, most of these tools are for general purpose, and targets a very wide range of user groups, including strategy consultants, business analysts, process specialists, IT architects, software developers, etc. Both business and IT organizations need manipulate business processes, however, they focus on different facets of business processes and talk with different languages, thus they have dif-

ferent manners and preferences in using the tools. It is hard for a strategy consultant to play with things like software configurations. These general-purpose tools cover more user groups, but for the specific users, such as business consultants, they do not take special care.

This paper will introduce an effort in IBM Research division named Supply Chain Process Modeler (SCPM), which aims at providing a tailored business process modeling and simulation environment right for business users. We believe a good business process equals to the rational process flows plus appropriate decision rules within the process, so SCPM mainly focuses on these two aspects. In order to support building rational process flows, we develop a business process model repository that includes a lot of reference models, industry standards, and best practices, which serve as the template of business process modeling. We also provide a flexible process simulation environment that enables the users to conduct simulation at different level of complexity with different efforts, which is effective in supporting the design of both rational process flows and appropriate decision rules.

The remainder of this paper is structured as follows. At first, a literature review on related topics including business process models, business process simulation, and business process modeling and simulation tools, is performed in Section 2. Then in Section 3, we present the technical details of SCPM, which focuses on two main modules, the business process model repository, and the scripts-based simulation mechanism. A case study is briefly introduced in Section 4 to illustrate how SCPM works in business process simulation. Finally, in Section 5, we conclude with some closing remarks.

2 LITERATURE REVIEW

A variety of definitions of business process are available in the literature (Davenport and Short 1990, Hammer and Champy 1993). Hammer and Champy (1993) defined a business process as “a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer”. Quality and efficiency of business processes have a significant effect on turnover and profit, and thus the long-term success of a company. For the implementation of the business strategy, a company therefore requires, along with flexibility in its business processes, a high level of innovation and the ability to transfer process optimizations and innovations from management concepts to the world of IT systems. Business applications only become business solutions with efficient process configuration. The added value of the company’s IT and IT-related investments are realized through the support of its processes.

Business process management (BPM) is the concept of achieving business innovation and optimization by implementing business strategy through modeling, developing, deploying and managing business processes throughout

their entire lifecycle (Wahli et al. 2006). BPM combines business processes, information, and IT resources, aligns an organization's core assets (people, information, technology, and processes) to create a single integrated view, with real-time intelligence of both its business measurements and IT system performance. There are typically four major steps in a BPM lifecycle, i.e., model, assemble, deploy, and manage. But in this paper, we just focus on the first step – model, which is to capture, simulate, analyze and optimize business process models to reduce risk and increase flexibility.

2.1 Business Process Models

Organizations have various objectives for modeling business processes, such as modeling for compliance or documentation (such as legal, regulatory, training, etc.), modeling for process redesign, and modeling for execution. No matter which purpose the modeling is for, the output would be business process models in certain format. An appropriate business process model is the prerequisite of effective business process management, thus it is necessary to follow some business process modeling standards, such as (Wang et al. 2006),

- **BPMN** – Business Process Modeling Notation (BPMN) is a standardized graphical notation for modeling business processes. The notation is strongly IT-oriented, which is maintained by Object Management Group (OMG).
- **BPEL4WS** – Business Process Execution Language for Web Services (BPEL4WS) is a technical standard used to describe executable process models based on Web Services.
- **WSDL** – Web Services Description Language (WSDL) is an XML-based standard for describing Web Services interfaces.
- **EPC** – Event-driven Process Chains (EPCs) are a leading standard for modeling business processes, which was developed within the ARIS framework by Dr. Scheer.
- **XPDL** – XML Process Definition Language (XPDL) is a process definition language proposed by Workflow Management Coalition (WfMC), which defines a common interchange format supporting the transfer of process definition between different products.
- **UML** – Unified Modeling Language (UML) is a leading standardized specification language for object modeling in the software engineering domain by OMG.

Besides the above standards, there are also many other business process modeling methods, such as Petri Net, IDEF0 and IDEF3, etc. Among these standards, BPMN and EPC are originally designed for business process modeling, BPEL4WS, WSDL, XPDL, and IDEF0/IDEL3 are general-purpose process modeling methods, but they can support

business process modeling, while UML and Petri Net are designed for other purposes, but they can be leveraged to be used in business process modeling.

These standards focus on different aspects of business process management, e.g., BPMN and EPC are designed for the logical and visual representation of processes, while BPEL4WS, WSDL and XPDL are more execution-oriented. People should determine to follow different standards and model at different level of granularity based on real requirements.

2.2 Business Process Simulation

In order to design, redesign, understand and improve business processes, people are using various methods and techniques. Figure 2 classifies these techniques into three categories based on the popularity and complexity.

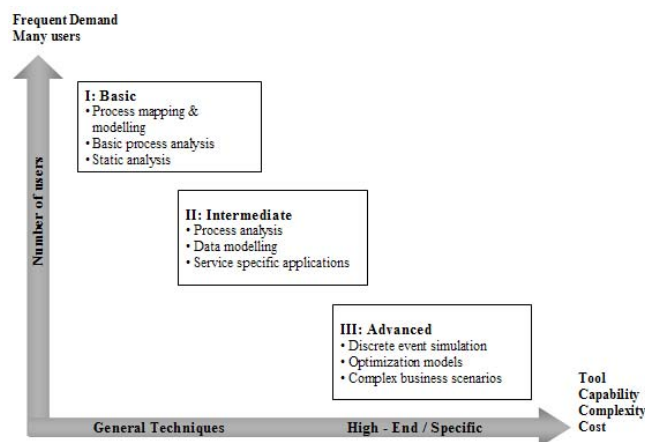


Figure 2: Classification of business process modeling and analysis techniques

We have to admit the fact that most of current business process initiatives are doing the “diagramming” jobs, which focus on business process mapping with limited analyses. Some projects consider also process data, and conduct some analyses to diagnose and design business processes. The advanced techniques such as simulation and optimization are not widely used in practice, which is partly limited by the time, cost, requirement and user skills. In order to understand the requirements of people engaged in business process simulation, Melao and Pidd (2003) conducted a survey among potential business process simulation users. The survey revealed a low usage of simulation in the design, modification and improvement of business processes. It confirms that business process simulation projects are typically short, relatively non-technical, and rely on good project management for their success.

But under complex business scenarios, dynamic simulation is the only technique that enables users to accurately model, analyse, visualise, quantify and verify dynamic sys-

tem behaviour and performance over time, evaluate effects of variability, variance, stochastic processes such as breakdowns, random failures, etc., and study complex interactions and interdependencies between processes and resources, operational rules, and logical constraints.

By introducing dynamic parameters (such as times, volumes, capacities and quality) of the process, simulation fundamentally enhances process performance analysis. It provides a much better picture of bottlenecks, hand-over times and dynamic performance than a static analysis (such as by flow charts). Investigations and analyses necessary to build the simulation model improve the knowledge about the process itself, which leads to valuable ideas for future process design. Any envisaged changes in process design can then be anticipated and evaluated by simulation. Thus experimental results significantly contribute to the decisions about future process design. Business process simulation can also increase the acceptance of redesign solutions. Graphical animation communicates what is going to change. Simulation experiments explain why change happens, i.e. which kinds of improvement are achieved by the redesign (Aguilar et al. 1999).

From the technology point of view, there are two methods for business process simulation, i.e., system analysis (continuous and discrete simulations based on mathematical models and numerical methods) and discrete event simulation (DES) based on an event-handling method. System analysis-based simulation is mostly associated with academic studies, while DES is easily driven by the events that are generated in a business process, thus it is widely used in business process simulation tools.

2.3 Business Process Modeling and Simulation Tools

A lot of COTS tools are available for business process modeling and simulation. A majority of these tools have an origin in a variety of process mapping tools that provide the user with a static view of the processes being studied, but some of them are also able to show a dynamic change in business processes and evaluate the stochastic events and random behavior of resources.

Typically, the software tools that may be applicable for business process modelling and simulation can be classified into two main categories: general purpose DES tools and business process modelling tools (Bosilj-Vuksic et al. 2007). Nowadays, typical general purpose DES tools provide the following functions (Pidd and Carvalho 2006),

- Modeling tools: a graphical modeling environment, built-in simulation objects with defined properties and behaviour, sampling routines, property sheets and visual controls.
- Tools to execute the simulation: a simulation controller to run a model, animated graphic, virtual re-

ality representation and user interaction with the simulation as it runs.

- Tools to support experiment: define run lengths and parameters, enable optimization, results interpretation and presentation.
- Links to other software (spreadsheets, databases, ERP systems, etc.).

In order to evaluate various business process modeling and simulation tools, Bosilj-Vuksic et al. (2007) proposed an evaluation framework, in which the criteria was classified into four main groups as below,

- Hardware and software considerations: coding aspects, software compatibility, user support, financial and technical features, pedigree.
- Modeling capabilities: general features, modeling assistance.
- Simulation capabilities: visual aspects, efficiency, testability, experimentation facilities, statistical facilities.
- Input/Output issues: input and output capabilities, analysis capabilities.

Hall and Harmon (2006) conducted a detailed analysis of business process modeling and simulation tools, which includes most of the mainstream products, such as IDS Scheer's ARIS, IBM's WebSphere Business Modeler, Proforma Corporation's ProVision, iGrafx's iGrafx, MEGA's MEGA Suite, BOC's ADONIS, CACTI's SIMPROCESS, etc. Readers can refer to the report for more details about the evaluation of different COTS tools.

IBM WebSphere Business Modeler (WBM) is a business process modeling and analysis tool that enables users to model, design, simulate, analyze and generate reports for business processes, integrate new and revised process, and define organizations, resources and business items. (Wahli et al. 2006). IBM WBM is a critical component of IBM's BPM Suite, and it is also used as the foundation for our SCPM effort.

3 SUPPLY CHAIN PROCESS MODELER (SCPM)

3.1 SCPM Overview

Like other leading business process modeling and simulation tools, IBM WBM provides powerful and friendly enough modeling and analysis capabilities. However, positioned as a general purpose tool, it has to cover both business and technical users, thus it can hardly consider some special requirements from special user groups. Moreover, as a commercial software product, it has to control the usability to certain extent so as to shorten the learning cycle, which limits the flexibility of the tool.

As a major user group of business process modeling and simulation tools, business consultants have their special requirements. First of all, from a business consultant's point of view, the main challenge of process modeling is not the

tool itself, but how to abstract business processes from real world business operations, i.e., the difficulty mainly lies in the process of understanding specific business processes and expressing them in a logical way, while not the concrete expression modes. Secondly, consultants may encounter various processes and scenarios, so they need model different logics when running simulation, which requires the flexibility of simulation modeling. Moreover, the main objective of consultants is to deliver process modeling and simulation results to clients, so they have some special requirements for project delivery, such as customized documentation support.

Basically, SCPM is an WBM add-on to provide tailored business process modeling and simulation environment for business consultants. In order to overcome the modeling difficulty, we build a business process model repository with a collection of reference models, industry best practices, project references and models for packaged applications (such as SAP), which is the good foundation for a quick and effective business process modeling from scratch. For the simulation flexibility, we extend the WBM simulation engine and allow users to write simulation scripts so that enables the flexible modeling of much more simulation logics. Moreover, SCPM also provides tailored features such as generating customized reports that can be used for project delivery, step-by-step modeling wizard to ease the modeling process, etc.

Figure 3 gives a brief architecture of SCPM.

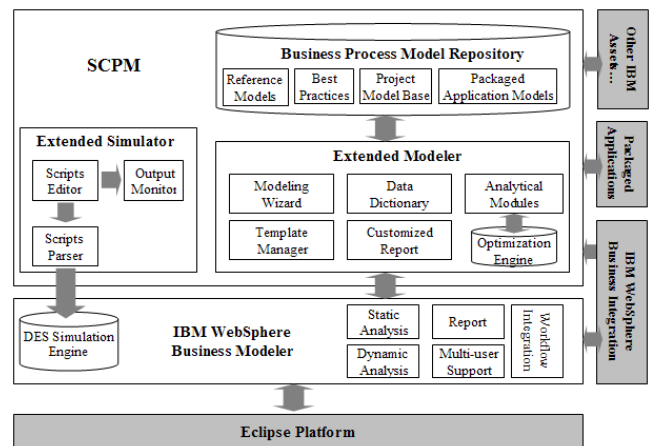


Figure 3: SCPM architecture

From the software technology point of view, SCPM seamlessly “plugs in” the WBM platform. WBM is built on Eclipse, which is an open source platform to build Integrated Development Environment (IDE) and applications. The universal and open development framework enables the seamless integration and easy extensibility of SCPM. This represents our basic idea of how we balance the usability and flexibility of business process modeling and simulation tools. We think it is necessary to keep a general purpose

software with common functionalities, while leaving the special support as software add-ons, which can be easily and seamlessly integrated with the general tool. Certainly, the open software architecture is the foundation to realize such an idea.

In the following subsections, we will introduce the business process model repository and extended simulator in detail.

3.2 Business Process Model Repository

Business process modeling is often time-consuming and sometimes involves a certain amount of redundant work because of the similarity between modeling objects. Domain knowledge is crucial to an effective business process modeling, so it is in urgent need to make a better use of previous models and/or reference models to support the business process description and design. In order to deal with these challenges, SCPM provides a business process model repository to store, manage, and accumulate knowledge on business process modeling.

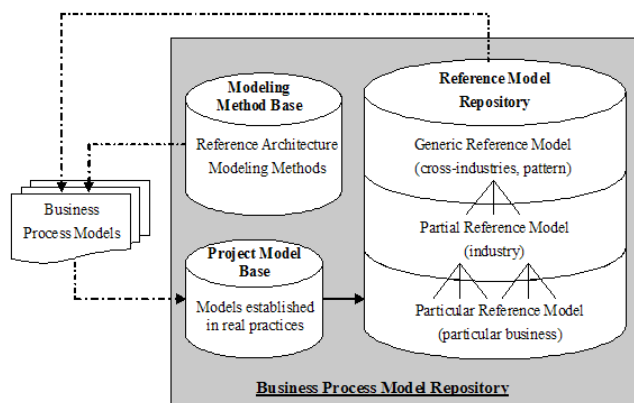


Figure 4: Business process model repository

The reference models in the repository are organized by three levels: generic, partial and particular (see Figure 4). Generic reference model repository stores standardized cross-industry models provided by international industrial organizations such as the SCOR (Supply Chain Operations Reference) model (SCC 2008) and APQC PCF (American Productivity and Quality Center Process Classification Framework) (APQC 2008), particular reference model repository stores particular business process models abstracted from real projects, while partial reference model repository is located between generic and particular level which stores models covering certain particular industries.

The model repository also includes various industry best practices, including typical business processes, input and output logics, organizations, roles, resource and data definitions, performance measures, and benchmarks. The

knowledge accumulation and management mechanism enables a continuous self-improvement of the repository.

3.3 Extended Business Process Simulator

WBM provides a powerful and industry-neutral business process simulation engine, based on which analysts are able to estimate resource allocation, total processing time, cost/revenue caused by tasks, etc. However, since it is for general purpose, it is not easy to model complex simulation logics outside basic WBM functionalities. In order to make it flexible, a simulation scripts mechanism is developed in SCPM. Figure 5 depicts the architecture of the scripts-based mechanism.

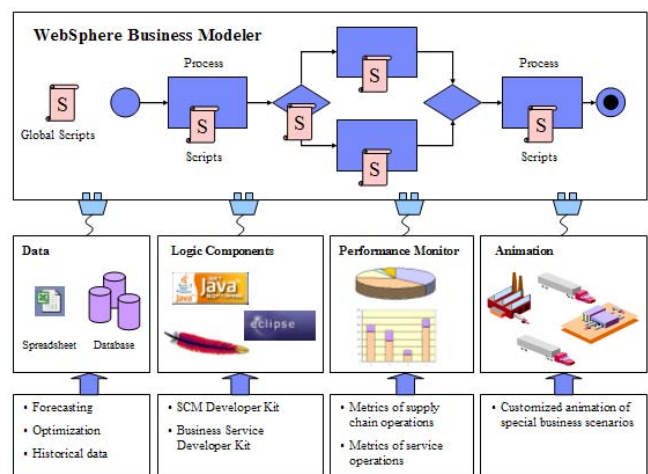


Figure 5: Scripts-based business process simulation

The simulation scripts are very like standard Java language. Users can write simulation scripts for process elements, including process steps and decision branches. The below six basic types of scripts are supported,

- **Pre-Process** scripts will be executed as soon as the process/task is activated.
- **Post-Process** scripts will be executed at the end of the process/task (after delay time).
- **Delay** scripts define the delay time for the process/task.
- **Cost** scripts define the cost for the process/task.
- **Revenue** scripts define the revenue for the process/task.
- **Duration** scripts define the duration for the process/task.

When instances of process elements are created and executed during a standard WBM simulation, the scripts attached are evaluated accordingly. Scripts here could be used to initialize a simulation run, to set task attributes, such as processing time, cost, revenue, resource allocation, and to set complex decision rules for a decision node. The scripts can also be used to access details of the process simulation

engine and token-flow, and even be used to invoke external components, such as the optimization engines and libraries, which makes the simulator highly extensible. In addition, SCPM can also create customized text or graphical outputs on monitor panels.

Although basic coding skills are needed to use SCPM extended simulator in a programming way, it provides great flexibility to business consultants. They can model complex logics and define execution flow for special purposes as needed.

4 CASE STUDY

Having been accepted as a standard business process modeling and simulation tool by IBM Global Business Services (GBS) division, SCPM has been widely used in a lot of real practices for business process modeling and simulation in various industries, such as high-tech manufacturing, automotive, steel, chemical, insurance, etc. Through the practices, we have built up business process templates for 17 typical industries in the business process model repository. Due to the space limitation, we just briefly introduce a typical case, where SCPM has been used as the major supporting tool for business process simulation.

The client is a large steel maker in Asia, and the project is among a big supply chain transformation initiative which includes strategy formation, process design, and IT system implementation. SCPM was chosen as the business process modeling and simulation tool. Besides the business process modeling, a key problem in the project is to improve the steel-melting shop (S.M.S.) process. Figure 6 illustrates a general S.M.S. process.

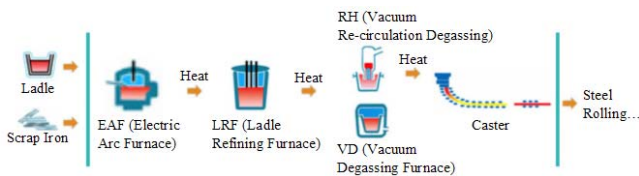


Figure 6: The S.M.S. process

In this project, the client has 2 EAFs, 3 LRFs, 1 VD, 1 RH, and 3 Casters. The EAFs release heat every 48 minutes, and then the heats go into LRFs for refining. Based on the products to be casted, the LRFs have two different processing time, i.e., 60 minutes for VD/RH heats, and 40 minutes for non VD/RH heats. The VD/RH heats will enter VD or RH for degassing before going to casters, while the non VD/RH heats will directly enter casters for casting. Each of the 3 casters can cast several products (non-overlapped), and the casting time depends on the product type. There are two heat decisions along with the S.M.S. process, one is choosing LRFs, and the other is choosing casters. Basically the path of a heat in the process is determined by the product it will be used to cast, so given the product to be pro-

duced, the caster selection is not a problem. The LRF selection is currently done manually based on experiences, and a basic rule is to balance the workload of all the 3 LRFs. So the key problem is to determine which product to produce for each heat, because different production sequence may lead to different production cycle time and thus different throughput. The main objective of the project is to find a near optimal policy for heat sequence decision to maximize the throughput of the S.M.S. process.

The heat decision policy is embodied in the heat sequence when the production plan is confirmed, so from the simulation modeling's point of view, this study is to simulate the heat flow in the S.M.S. process and evaluate the throughput of the shop given some specific heat sequences. In order to build the simulation model, there are some special requirements which can not be realized by standard modeling logics in WBM (and in most of the COTS business process modeling and simulation tools), such as,

- Modeling complex decision rules

For example, in the LRF decision, we need to model the decision rules like “If a heat has been processed at any LRF for more than 20 minutes, then plan the next heat for this LRF”.

- Modeling complex logics

The caster needs to change its mould after casting several heats, or changing different products. So there is a changeover time occurred for a caster when 1) the caster has continuously casted a certain number heats, or 2) the caster has a production switch. This logic is very hard to model.

- Manipulating files during simulation

Since the simulation is triggered by a given heat sequence, so it requires to import the heat sequence from the file (.txt, .csv, or .xls) which contains such information. Moreover, some simulation results also need to be exported to data files.

The scripts mechanism in SCPM enables to solve the above issues. Firstly, we model the basic S.M.S. flow with WBM as shown in Figure 7.

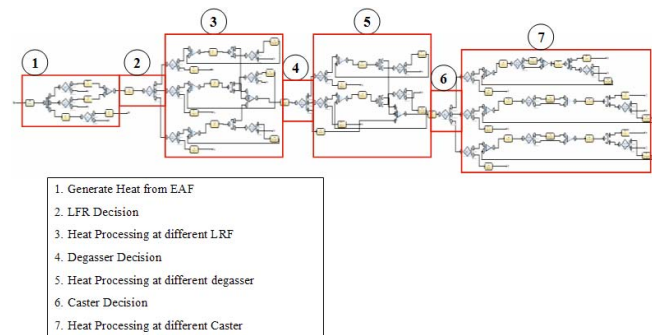


Figure 7: The S.M.S. process in WBM

Then we write scripts to realize the special logics listed above. Figure 8 shows how to express the changeover logic for a caster. There is a script view in SCPM to allow users edit simulation scripts.

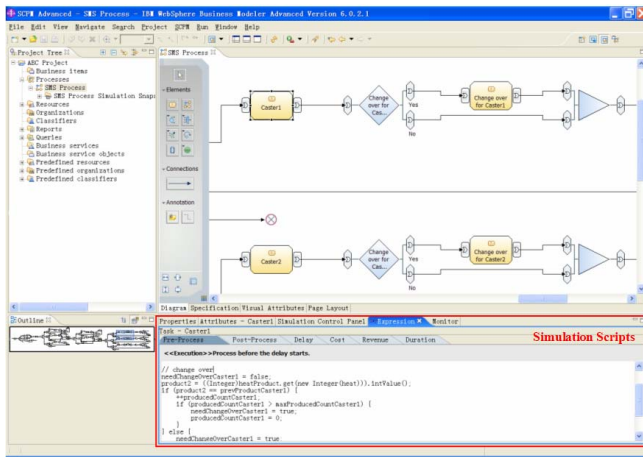


Figure 8: Simulation scripts for caster changeover

It is easy and very flexible to use the scripts mechanism, which is just like programming with Java. Figure 9 gives an example of how to read the heat sequence information from a file (heat.csv) as the input for the simulation run.

```
String heatFile = "C:/heat.csv";
String line = null;
StringTokenizer st;
int[] tokens = new int[6];
BufferedReader in = new BufferedReader(new FileReader(heatFile));
while ((line = in.readLine()) != null) {
    i = 0;
    st = new StringTokenizer(line, ",");
    while (st.hasMoreTokens()) {
        tokens[i++] = Integer.parseInt(st.nextToken());
    }
    if (i >= 6) {
        heatProduct.put(new Integer(tokens[0]), new Integer(tokens[1]));
        heatVD.put(new Integer(tokens[0]), new Integer(tokens[2]));
        heatRH.put(new Integer(tokens[0]), new Integer(tokens[3]));
        heatCaster.put(new Integer(tokens[0]), new Integer(tokens[4]));
        heatCastingTime.put(new Integer(tokens[0]), new Integer(tokens[5]));
        ++totalHeat;
    }
}
in.close();
```

Figure 9: Simulation scripts for reading a file

By running simulation with different scenarios, we evaluate different heat decision policies and then give suggestions to the clients. Since including this case here is more intended to illustrate how to use SCPM in simulation modeling, while not to explain the detailed results of the study, so we ignore the numerical results.

5 CONCLUSIONS

This paper introduces an IBM asset SCPM, which provides a tailored business process modeling and simulation environment for business consultants. This effort represents a viewpoint how we try to achieve a better trade-off between usability and flexibility of a business process tool. This tool has already been verified and enhanced through a lot of real consulting practices.

This paper is intended to describe the basic design idea and main framework of SCPM, rather than elaborate all technical details for the limitation of space. Moreover, its contributions would be tested in further practices with necessary adjustments.

In terms of usefulness and utility, simulation fits ideally in the process transformation project. It can be used to analyze state maps and quantify proposed process transformations. But unfortunately, in practices simulation technology was not used much despite the apparent benefits of it. Surveys also verify that the data and static process modeling features of software tools were most widely used in practice, whereas the dynamic process modeling features were less frequently used. We think this is partially caused by the fact that in practice the improvement to a business process is either obvious or too hard to accurately model. Moreover, compressed project time frames are also a cause of little use of simulation modeling.

REFERENCES

- Aguilar, M., T. Rautert, and A.J.G. 1999. Business process simulation: a fundamental step supporting process centred management. In *Proceedings of the 1999 Winter Simulation Conference*, ed. P.A. Farrington, H.B. Nembhard, D.T. Sturrock, and G.W. Evans, 1383-1392. American Productivity and Quality Center (APQC). 2008. Process classification framework (version 5.0.0). Available via <http://www.apqc.org> [accessed May 16, 2008].
- Bosilj-Vuksic, V., V. Ceric, and V. Hlupic. 2007. Criteria for the evaluation of business process simulation tools. *Interdisciplinary Journal of Information, Knowledge, and Management 2*: 73-88.
- Davenport, T. H., and J. E. Short. 1990. The new industrial engineering: information technology and business process re-design. *Sloan Management Review 31*(4): 11-27.
- Hall, C., and P. Harmon. 2006. The 2006 enterprise architecture, process modelling & simulation tools report. Available via <http://www.bptrends.com> [accessed April 21, 2008].
- Hammer, M., and J. Champy. 1993. *Re-engineering the corporation: a manifesto for business revolution*. New York: Harper Collins.

- InformationWeek. 2004. Outlook 2004: priorities 1Q. InformationWeek Research Report.
- Melao, N., and M. Pidd. 2003. Use of business process simulation: a survey of practitioners. *Journal of the Operational Research Society* 54: 2-10.
- Pidd, M., and A. Carvalho. 2006. Simulation software: not the same yesterday, today or forever. *Journal of Simulation* 1: 7-20.
- Supply-Chain Council (SCC). 2008. SCOR 9.0 overview booklet. Available via <http://www.supply-chain.org> [accessed May 16, 2008].
- Wahli, U., L. Leybovich, E. Prevost, R. Scher, A. Venancio, S. Wiederkom, and N. MacKinnon. 2006. Business process management: modeling through monitoring using WebSphere v6 products. Available via <http://www.redbooks.ibm.com> [accessed January 10, 2008].
- Wang, W., H. Ding, J. Dong, and C. Ren. 2006. A comparison of business process modeling methods. In *Proceedings of 2006 IEEE International Conference on Service Operations and Logistics, and Informatics*, 1136-1141.

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