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RECONCILIATION OF BUSINESS AND SYSTEMS MODELLING VIA DISCRETE EVENT SIMULATION

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ABSTRACT

Modeling techniques have been productively applied to Business Process (BP) redesign. They have been also successfully employed to assist Information Technology (IT) applications design and development. However, although BP and IT interact in practice, suggesting that modeling in those areas should also be done in parallel, surprisingly few works have addressed the issue of integrated BP/IT modeling. In this paper we discuss the potential of discrete-event Business Process Simulation (BPS) and Computer Network Simulation (CNS) models to work in parallel to provide a link between the BP and IT modeling domains. To this end, we propose a modeling framework and a methodology for linking BPS and CNS models, and present an example case that demonstrates the practical feasibility and efficacy of the approach.

1 MODELING OF BUSINESS PROCESSES AND INFORMATION SYSTEMS

Since the 1980's and early 1990's a number of studies have concentrated on processes and the role that they play within the organization. Business Processes (BP) and the enabling role of Information Technology (IT) have become two of the most important application areas in contemporary management science.

In the business re-engineering arena, for example, changes are oriented to making major improvements in the organizational structure, questioning the way the organization has been functioning for years, and addressing the alignment between business operations and business objectives. Business Process Modeling techniques are oriented towards developing broad models of the way the organization operates, of what processes it has and of how they traverse the 'functional silos' (Hammer and Champy 1993), in order to give an understanding of possible scenarios for improvement (Ould 1995). Flowcharting, IDEF0, IDEF3, Petri Nets, System Dynamics, Knowledge-Based Techniques, Role Activity Diagrams, Activity Based Costing, and Discrete-Event Business Process Simulation (BPS) are only some examples of BP modeling techniques widely used in the organizational domain.

On the other hand, in the software engineering domain, IT modeling techniques have been extensively used for modeling different aspects and supporting various stages of the systems design and development process. Such representation schemes have been thought to have significant importance in clarifying the interrelationships and interactions of interest in IT. The IT modeling domain can be separated into two major areas of study, namely Information Systems (IS) and Computer Networks (CN). Data Flow Diagrams, Entity Relationship Diagrams, State-Transition Diagrams, IDEF1x, CASE Tools, and Workflow Management Systems can be mentioned as examples of the dominant IS modeling techniques, whereas the Computer Network Simulation (CNS) technique has been widely used to model the communication infrastructure that supports IS and organizational processes. However, our study will not just focus on the data communication modeling aspects that CNS supports but also in the ability of CNS to model IS applications that produce the traffic load. This characteristic, according to us, places CNS as a particular technique that can also be used to model IS from a different angle to the aforementioned IS modeling techniques.

2 BP/IT MODELING PERSPECTIVES

The fact that business processes can be targeted on different application areas suggests that business processes may be studied and analyzed from different viewpoints. The goals of a particular study will necessarily impact the uses to which a model will be put and influence the requirements posed on the process techniques to be employed (Liles and Presley 1996). Table 1 illustrates typical process modeling goals and objectives, along with associated requirements for modeling techniques in each case (Curtis et al. 1992).

To be able to accommodate the aforementioned goals and objectives, a model must be capable of providing various information elements to its users. Such elements include, for example, what activities comprise the process, who is performing these activities, when and where are these activities performed, how and why are they executed, and what data elements they manipulate. Modeling techniques differ in the extent to which their constructs highlight the information that answers these questions. To provide this information, a modeling technique should be capable of representing one or more of the following *modeling perspectives* (Curtis et al. 1992):

- *Functional perspective*: Represents what process elements (activities) are being performed.
- *Behavioral perspective*: Represents when activities are performed (for example, sequencing), as well as aspects of how they are performed through feedback loops, iteration, decision-making conditions, entry and exit criteria, and so on.
- *Organizational perspective*: Represents where and by whom activities are performed, the physical communication mechanisms used for transfer of entities, and the physical media and locations used for storing entities.
- *Informational perspective*: Represents the informational entities (data) produced or manipulated by a process and their relationships.

The multiplicity of modeling objectives, as well as the diversity of the aforementioned perspectives, renders the development of a 'holistic' modeling technique that would be applicable in all contexts extremely arduous. Furthermore, such an approach would probably result in complex models, thus reducing the ease of use for any single particular application. To deal with this problem of complexity, various techniques have been proposed, each concentrated on addressing specific parts of organizational design and providing support for specific modeling goals and objectives (Curtis et al. 1992). By providing constructs and concepts that allow for modeling only specific views of an organization, a technique can maintain its appropriateness and usability for its intended use, but cannot be effectively utilized across different organizational projects (Curtis et al. 1992).

3 INTEGRATING MODELING PERSPECTIVES

Information Technology is a well-known enabler of business change. Childe et al. (1994) state that the initiative to move towards BPR in many cases originates from the IT departments. Davenport (1990) affirms that, when used together, Information Technology and Business Process Redesign have the potential to create a new type of industrial engineering.

Although IT and BP should be studied and examined together, this does not seem to be the case in many practical situations. Business process modelers and IS modelers have traditionally had different roles within organizations, each equipped with their own tools and techniques (Earl 1994). There is a surprising lack of BP or IS modeling techniques designed to cope with *all* of the aforementioned modeling perspectives. We contend that BP modeling techniques typically view the modeled system from *organizational*, *functional* and/or *behavioral* perspectives. The *informational* perspective is barely considered or, in many cases, totally omitted. On the other hand, traditional IS modeling techniques are strongly oriented to developing models from an *informational* perspective, without considering, again in their majority, the other perspectives in great detail. The following example of an ordering process may help to clarify this point.

A business analyst will initially focus on what activities are performed in the process (*functional perspective*), such as receiving the order, forwarding it to the production line, and so on. The next step may be to investigate the sequence that these activities follow and how they are performed and develop a graphical picture of the process (*behavioral* perspective). Finally, the business analyst may study where these activities take place and which resources (human, mechanical or electronic) are used. This information will suffice, at least from the analyst's viewpoint, to develop a BP model (for example, a discrete-event simulation). The BP analyst will not

Table 1: Modeling Goals and Requirements (adapted from Curtis et al. 1992)

Modeling Goals and Objectives	**Requirements for Modeling Techniques**
Facilitate Human Understanding and Communication	Support Comprehensibility, Communicability
Support Process Improvement	Model Process Components, Reusability, Measurability, Comparability, Support Technology Selection and Incorporation, Support Process Evolution
Support Process Management	Support Reasoning, Forecasting, Measurement, Monitoring, Management, and Co-ordination
Automated Guidance in Performing Process	Integrate with development environments, Support for Process Documentation, Reusability
Automated Execution Support	Automate Process Tasks, Support Co-operative Work, Automate Performance Measurement, Check Process Integrity

necessarily consider the detailed data produced and managed by the process.

On the other hand, the same process from an IT viewpoint may require a radically different analysis. An IS analyst will certainly have to focus on the data that an order contains (for example, dates, quantities and prices), where the order data will be stored (in terms of database design), and so on.

This simple example highlights how modeling the same process may result in 'incompatible' models (i.e. models that focus on different perspectives and thus have little potential of communication and integration). However, such an integration is highly desirable when, for example, the IS analyst wants to use the BP design as an initial specification of the system to be developed or when the business analysts want to assess the effect of alternative IS on the performance of the business process under investigation.

To this day, none of the extant modeling techniques possesses enough functionality to accommodate the need for such integrated design. An exception to this rule may be the use of the IDEF suite of modeling techniques (Mayer et al. 1995), perhaps by integrating IDEF0/3 and IDEF1x. However, IDEF suffers from a mainly static (or pseudo-dynamic) nature that renders the technique unsuitable for true time-dependent modeling and analysis. To address this need as well, in this paper we consider the possibility to use discrete-event simulation for integrated BP/IT modeling. Before illustrating our proposal in more detail, we will turn to an introductory discussion of the two simulation application areas to be addressed: Business Process Simulation (BPS) and Computer Network Simulation (CNS).

4 AN OVERVIEW OF BPS AND CNS

Business Process Simulation (BPS) has been mentioned by many researchers as a technique that could be helpful in the context of business process change (for example, Lewis 1993, Ardhaldjian and Fahner 1993). MacArthur et al. (1994), in one of the first articles specifically concerned with discrete-event simulation of business processes, investigate the suitability of simulation for BPR projects. The authors argue that simulation is well suited as a design assessment tool in the context of evaluating process change alternatives. Furthermore, Kettinger et al. (1997) argue that there is a need for more user-friendly and 'media-rich' capture of business processes and simulation can accommodate these requirements by providing easy visualization and allowing team participation in process redesign.

Since BPS looks to be a very suitable tool for the organizational domain, we proceed to look at the modeling perspectives that BPS can effectively take into consideration. The advantages of simulation presented in Banks et al. (1997) suggest that BPS is able to address at least the *functional*, *behavioral* and *organizational* perspectives. Not unexpectedly, BPS (being a BP modeling technique) barely focuses on the data that is generated by the model.

On a separate note, *Computer Network Simulation (CNS)* is being used with increasing frequency in the designing of computer networks (Sauer and McNair 1983). CNS models are powerful tools that help network engineers to identify and predict networking problems, the effects of loading, interconnections, change of protocols, and so on, by providing the opportunity to measure the impact of changing the communication infrastructure of an organization. Furthermore, CNS tools are also able to model an information system that contributes to the CN traffic load. A distributed system can be included in the CN model by inserting computer groups and processing nodes and specifying the transactions that are taken between them in terms of messages and response commands.

In summary a CNS model can be designed to address special objectives. The following list is a resume of the most relevant CNS objectives (derived from Law and McComas 1996):

- To measure the effects of increasing or reducing traffic on network performance.
- To measure the impact of a link failure.
- To test protocols for best network performance.
- To choose the best design for a new communications network.
- To measure the impacts of additional PCs on a LAN.
- To measure the effect of adding a new application on a LAN.
- To choose the best client-server strategy.

The aforementioned objectives suggest that a CNS model will, almost by definition, focus on the data communication factors that affect the network performance. Still, the last objective suggests that a CNS model can be used to study, not only the aforementioned CN factors, but also the behavior and performance of the information systems that are placed on the network. In other words, a CNS model is able to cope with the *informational* modeling perspective. From the network engineer's point of view, there is limited need for looking at the rest of the modeling perspectives.

It may thus be inferred that there is a potential opportunity in bridging BPS and CNS modeling tools to address *all* modeling perspectives and hence support the requirements of integrated BP/IT modeling. Since however this is easier said than done, in the remainder of the paper we will outline a potential approach to addressing this integration in practice.

5 A FRAMEWORK FOR INTEGRATED BP/CN SIMULATION

The framework discussed in this section is based on a real-life case study that was carried out as part of a wider research project funded by the UK government. More information on the ASSESS-IT project can be obtained at the project's web site (http://www.brunel.ac.uk/research/assessit), as well as in Giaglis et al. (1999) and Eatock et al. (1999).

Let us consider a relatively simple case. An organization receives orders from its customers, checks the orders against its inventory, and dispatches the goods to the customers. However, due to inefficiencies in the production and inventory processes, a percentage of the orders received (say, 30%) require some products that are currently out of stock. For these orders, the organization dispatches the goods that are in stock and creates a backorder for the out-of-stock goods. It is anticipated that a new computer system will improve the overall business process, thereby reducing the number of backorders, and hence the workload required. The problem is to determine the percentage by which the backorders will be decreased as a result of this system's introduction. As the degree of reduction to the number of backorders is crucial to the efficiency of the process as a whole, the need to accurately assess it is imperative. The problem is how can we accurately assess this decrease?

Two models of the above scenario were built, one reflecting the activities at the business process level (to maintain the wider picture during experimentation and decision-making), and the other representing the new computer network that was to be installed as part of the new computerized system (to address the low-level technical considerations of alternative system designs and their effects on the wider process). The models were built using CACI's Simprocess and Comnet simulators respectively. It was initially intended to link these models into a 'holistic' BP/IT simulation.

However, it quickly became apparent that the two models were working at radically different levels of abstraction. The BPS model is dealing with orders (organizational, behavioral and functional perspectives), and does not consider the products that are ordered on an individual basis, whilst the computer network is dealing with the databases, and therefore with individual products (informational perspective).

For example, as stated 30% of the orders produce backorders, but this figure does not indicate how many of the products from each order are missing. At the business process level, the fact that an order produces a backorder or not is all that is relevant, whereas at the computer network level, the total of different products that a backorder contains will be proportional to the traffic in the communication links. This means that each product that is needed in a backorder must be sent over the network. In data communication terms, this can be represented either, as the transmission of a message for each product, or the total of products in a single message, in which case the message size will vary. The more product variety in a backorder, the higher the number of transmissions or message sizes needed. These added figures produce an increased traffic load and affect the whole process. Therefore it is instrumental in obtaining a system-wide level of the modeled process.

Further refinement to the BP model needs to be made in order to cope with the aforementioned case. Since the BPS model does not consider the informational viewpoint, an alternative approach might involve defining an informational stage that represents the IS within the BP model, which we shall name BP/IS level. It will also be used to model the same IS from an informational perspective, using the facilities that the CNS tool has for specifying IS applications over a specific network. This stage may be possible by inserting a 'sub-model' to the BP model (Figure 1). The main advantage of this design over the previous one is that now any changes in the information system level are automatically reflected in the business process model, and vice versa, without the need to transfer data between the models. This approach is feasible in any business process simulators that allows for hierarchical decomposition of models and design modularity in model development (Giaglis et al. 1996).

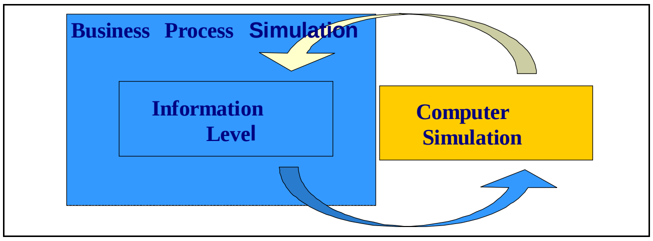

Figure 1: BP/CN Simulation Integration Approach

The complexity and the need to build two distinct models of one system implies that the proposed method may be only economically attractive when the BP model is sensitive to changes at the CN level (as is the case in our example). This could be verified by a sensitivity analysis on the basic BP model (against those parameters affected by the CN model).

The entities that traverse the IT level of the business model can generally be conceived to represent physical documents (e.g. an order, an invoice, a dispatch note), while those that traverse the communication links within the CN model can be considered as detailed data (e.g. client code, product code, product quantity). For the purposes of the framework proposed, the entities that are defined in the BP level and are used on IS processes will be named Record Entities (REs). The information that a RE conveys will be separated into its component parts

(Figure 2), which are called Field Entities (FEs). Figure 3 shows the IS level of the business process model for the process example discussed above.

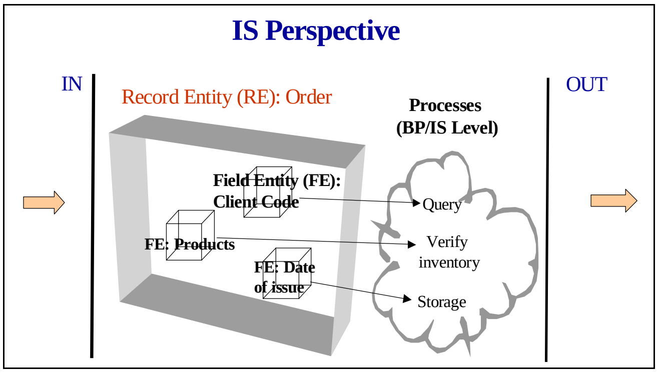

Figure 2: Record Entities and Field Entities

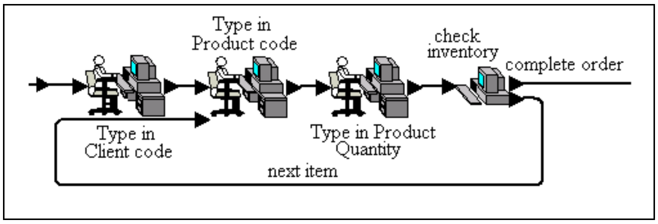

Figure 3: The BP/IS Level

There are three basic transactions that can be carried out when a transmission of data (FEs) to a remote or local host is made:

a) *read* data transaction
b) *write* data transaction
c) *procedure* transaction. We define as a *procedure* when there is a data processing (numeric or/and relational data operations) at the BP/IS level.

These transactions must have been indicated at the BP/IS level. If any Read, write and/or procedure transactions involve the use of more than one FE entity, this must be clearly specified at this level.

The information that will be shared between the BP/IS level and the CNS model is mainly composed of the type of transactions, and the size, direction and frequency of the FE's. Simprocess provides access to a file that is attached to each activity (represented as PC icons in figure 3) and can be used to keep track of the aforementioned information. An example of how a file looks like is presented in Figure 4. We propose the following procedure to record the information that will be exchanged between Simprocess and Comnet tools.

Description: FE name: Cli_Cod,Client code
Input: Cli_Cod(Uni(100,220) secs)
Output: Cli_Nam (FE:100 bytes)
Category: (VA/NVA)
Owner: Order(DE)
Direction: ABC server
File Used: Clients
Process: Query

Figure 4: FE Simprocess Information File (example)

Simprocess automatically generates five fields in each file to which we have added three more: direction, file used and process.

The name of the FE or RE and a description of the entity must be recorded in the *Description* field. The *Input* field is used to describe the incoming entity and its arrival rate and size (in bytes). The *Output* field will be used to describe the size, the departure rate and the name of the FE that will be the output from the transaction. The *Category* field is filled by default by Simprocess and is not used in this framework. The *Owner* field is used to describe the parent RE of the FE.

The *Direction* field identifies the FE destination server, while *File Used* indicates the main file where the FE performs its transaction (write, read or procedure). Finally, the *Process* field describes the process involved in the transaction (write, read or procedure).

The information contained within these files supply most of the information required for building the application sources, transaction and response commands as well as for specifying their correspondent arrival time in the computer network model. The next step of the methodology is to compile this information and transfer it to the CNS model. We have developed a procedure that produces a table to facilitate the information exchange between CNS and BP/IS level, which we shall title BP/IS table. An example of the contents of the BP/IS table is shown in Table 2 in the appendix.

BP/IS tables contain the necessary information to generate a CNS traffic model, using the data (REs and the corresponding FEs) of the business process. Read, write and procedure transactions may involve the use of more than one FE. In the example given, to store an order it is necessary to store the fields containing the client code, order number, and number of items among others, and they may be stored in different locations in the computer network. When the decomposition of these kinds of transactions is implied, it must be indicated in the process table by a '*Multiple transaction*' flag in the '*type of transaction*' field. The description of the FEs that are required to perform the multiple transaction can then be added to a new table, called *Transaction table*. In this table a new record is included at the end, which indicates the size, direction, and description of the output FE or RE of the transaction (see appendix, Table 3).

However, this decomposition may not end in this table and more FE transactions may be involved within the new transaction table, hence another decomposition is needed and a Sub-transaction table may be created from the previous transaction table. Thus, it can be perceived that there is a father-child relationship between the process, transaction, and sub-transactions tables.

The contents of all of the BP/IS tables and Transaction tables represent the majority of the information flow generated by the information system indicated in the BP/IS level. This, in turn, can be used to replicate the IS in the computer network model using the application sources provided by Comnet software.

6 CONCLUSIONS

We have identified that part of the organizational processes rely on IS to perform their tasks. We have also recognized that the organization's information systems are fundamentally designed to support organizational processes. Furthermore, these information systems must be supported by a reliable CN infrastructure. The question that naturally arises is how this relationship affects each of its constituent parts, namely BP, IS and CN? The framework proposed in this paper aims to provide the means to study this relationship by developing a model of the organizational processes including the underlying information systems and computer network infrastructure. It is relevant to remark that the computer network model in our framework focuses on the analysis of the performance of the IS over specific network scenarios, rather than the analysis of the organizational network infrastructure itself. Thus, our framework is based on two models that share information to analyze the same organization from different perspectives: the BPS model to study the organization from the functional, behavioral, and organizational perspective, and the CNS model to complement the remainder informational perspective. The BP/IS level that is added to the BPS model provides the information exchange between the two models.

The next step in this research will be to implement this framework and to analyze the possible effects that changes on the BP will produce on the designed IS and vice versa. Moreover, in order to advocate a dynamic information exchange, automated software mechanisms will be proposed.

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APPENDIX

Table 2: BP/IS Table Example

Ordering IS/BP level Table									
Origin	Times	FE name	Description	Size(bytes)	Direction	Type of transaction	Output	Size(bytes)	Process Involved
XYZ	1	Cli_Num	Client number	8	ABC (File:Clients)	Single Transaction	Client Data	80	Query
XYZ	1	Sal_Cod	Salesman Code	8	ABC (File:Salesmen)	Single Transaction	Salesman Data	80	Query
XYZ	n(1)	Process	Inventory		XYZ (File:Inventory)	Multiple Transaction	Authorization Status	4	Process
XYZ	1	Process	Order Storage		ABC (File:Orders)	Multiple Transaction	Storage Reply	4	Storage
Process Reply	*1*	*Process reply*	*Ordering process reply*		*Origin*	*Reply*			

Table 3: Transaction Table Example

Inventory Transaction Table									
Origin	Times	FE name	Description	Size(bytes)	Direction	Type of transaction	Output	Size(bytes)	Process Involved
XYZ	1	Pro_Cod	Product Code	10	XYZ	Single Transaction	None		Query
XYZ	1	Pro_Num	Number of products to purchase	8	XYZ	Single Transaction	None		Verification of Pro_Num with stock
Process Reply	*1*	*Aut_Sta*	*Authorization Status*		*Origin*	*Reply*			

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