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SIMULATION FOR INTRA- AND INTER-ORGANISATIONAL BUSINESS PROCESS MODELLING

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ABSTRACT

Business process modelling (BPM) is an increasingly emerging field of simulation application. Although it has been practically demonstrated that simulation can be an effective tool for business redesign, there does not exist a comprehensive framework to explain the characteristics of business processes and identify specific requirements for their modelling. Furthermore, hardly any attention has been paid to the modelling of inter-organisational business systems. In this paper, we examine the nature of business processes in the light of modern change management approaches and propose a set of requirements for their modelling. We then concentrate on inter-organisational processes and argue that modelling problems can be much more difficult to overcome when more than one business is involved, mainly due to the multiplicity of decision making levels involved and the subsequent need for multi-level output analysis. Based on an empirical study, we illustrate the practical problems of modelling inter-organisational business systems and suggest desirable characteristics of simulation packages for that purpose.

1 INTRODUCTION

A multitude of change management concepts have emerged during recent years to help modern enterprises in their efforts to adapt in a constantly changing business, social, and technological environment. The most popular of these approaches include:

- Business Process Re-engineering (BPR) (Hammer 1990, Davenport and Short 1990)
- Continuous Process Improvement (CPI) (Harrington 1991)
- Total Quality Management (TQM) (Oakland 1993)
- Organisational Transformation (OT) (Adams 1984)

Each approach differs significantly in the scope and range of the anticipated changes, the management tools utilised to achieve change, and the business contexts in which they can be used. However, they all have in common that they require businesses to model the ways in which they currently operate, to identify opportunities for change, and to design and implement alternative ways of carrying out business processes.

In view of the above, Business Process Modelling (BPM) has recently received widespread attention and has been acknowledged as an integral part of any change management project. Different tools and techniques have been proposed for BPM, and simulation has been identified as an extremely useful tool for this purpose (see for example Tumay 1995, Swami 1995, Bhaskar et al 1994). Despite the availability of these tools, it has been reported that companies are usually facing significant practical problems when trying to model in detail the way they operate (Hansen 1994) or to implement changes in existing environments (Galliers 1994).

Many reasons can be attributed to this difficulty, the primary ones being:

- the complexity of most real-world business processes
- their stochastic and usually unpredictable behaviour
- the interdependencies between individual tasks
- the informal nature of many tasks which makes their analysis and documentation profoundly problematic
- the different perceptions of users regarding the way in which work is being done.

Such modelling problems can become very significant in large, complex organisational settings, especially in cases where more than one business is involved (inter-organisational systems). For example, Business Process Re-engineering projects, where inter-organisational processes almost always play an important role (see for example Riggins and Mukhopadhyay 1994), have been reported to have a large proportion of failures in practice. In this paper, we first examine the nature of the problems of business modelling in general and identify a set of requirements that should be met if a process modelling exercise is to be successful. We then concentrate on the modelling of Inter-Organisational Business Processes and examine their distinct characteristics and requirements for modelling.

Simulation modelling is assessed as a potential tool for BPM (at intra- and inter-organisational levels). Finally, an example of inter-organisational business modelling is presented to help clarify some practical modelling problems that might arise.

2 BUSINESS PROCESSES: CHARACTERISTICS AND MODELLING REQUIREMENTS

2.1 Process-Based Organisational Approach

Most of the change management concepts identified above (especially BPR) adopt a new look to organisations based on the processes they perform rather than the functional units, divisions or departments they are divided into. Processes are defined as 'structured, measured sets of activities designed to produce a specified output' (Davenport 1993).

Typical examples of major business processes include the purchasing of raw materials from suppliers, the use of these materials to produce goods and/or services, the delivery of these goods/services to customers, the acquisition of new customers, the development of new products according to customer needs, etc. It is obvious that each of these processes requires the co-operation and synchronisation of different functional units in order to be successfully performed. It is also typical for a business process to cross organisational boundaries and extend to third parties (customers, suppliers, etc.). Of course, processes can be described at different levels of detail depending on the abstraction put into analysing the organisation. Typical business processes like those identified above, can be divided into sub-processes which can be further split until the level of individual business tasks.

2.2 Requirements for Business Process Modelling

It has been argued (Willcocks and Smith 1995, Galliers 1993) that businesses and business processes are sufficiently complex systems and therefore carefully developed models are necessary to understand their behaviour in order to be able to design new systems or improve the operation of existing ones. As businesses are essentially 'socio-technical' systems, we can distinguish the basic requirements of the decision makers regarding the modelling process in two separate areas: 'Technical' requirements which refer to those needs that call for the application of engineering principles in process analysis and design, and 'Political' requirements which refer to the needs that emerge from the social nature of business systems. These requirements include:

Technical Requirements

Formal Modelling. Formal engineering principles should be adopted during the modelling process in order to enable the development of models that can be readily understood and agreed upon by all parties, thus providing a common basis for decision making.

Quantitative Modelling. Managers need to have quantitative information that will allow for informed decision making (e.g. cost-benefit analysis) and for direct comparison between alternative system designs.

Stochastic Modelling. Modelling should take into account the stochastic nature of business processes, especially the way in which they are triggered by external factors and should allow for representation of and experimentation with situations where a great degree of uncertainty exists. Sensitivity analysis of business models becomes a significant issue in this case.

Model Documentation. Models should be easy to document for exchanging information between modellers, analysts, and decision makers. Model documentation can also be used as a reference in subsequent modelling exercises and/or if the model development teams change.

Model Adaptability/Reusability. Models should be easily updatable to follow changes in actual processes. Thus, they can be continuously used for future modelling exercises. Reusable models could assist in reducing the cost of model building and can provide an additional means of justifying the initial investment.

Objective-driven Modelling. BPM is usually performed having in mind specific business goals to be achieved through the process redesign exercise. The evaluation of alternative configurations is therefore highly dependent on the objectives of the particular study. Business models should reflect this requirement of decision makers and allow for output analysis that can be configured according to objectives so as to provide alternative views of measuring business performance.

Political/Social Requirements

Feasibility of alternative designs. Modelling and decision making in business contexts should take into account such factors as legislation restrictions, user acceptance of changes, etc. It is not sufficient to simply derive a particular system configuration that seems to optimise business performance, if the changes required in business processes cannot be practically implemented for this configuration.

Communication of Models. Business models are often used in brainstorming sessions of business management in order to assist in deciding changes. The models should therefore allow for easy communication of results between different parties. Moreover, generating alternatives and modifying the model during the decision making process is another very important aspect of business modelling, as managers clearly need to be able to interact with the models as new information or ideas emerge during brainstorming sessions.

User Friendliness. Modelling tools should be easy to use to allow users of the processes to be personally involved in the modelling exercise. The personal involvement of users should increase the confidence of the whole enterprise in the change initiative, thus enabling a greater degree of acceptability of the derived results.

Business Process Modelling approaches should combine the requirements identified above if they are to be proven useful tools for business decision making. In the next section we will assess the potential of simulation modelling as a suitable BPM technique.

2.3 Simulation as a Tool for Business Process Modelling

Simulation can be an invaluable tool for BPM, as it incorporates characteristics and capabilities that can accommodate all the requirements identified above.

Formal Modelling: Simulation is a formal and robust technique. It does not rely heavily on mathematical abstraction therefore it is suitable for modelling even complicated management systems (Pidd 1992).

Quantitative Modelling: Simulation is basically a numerical technique, therefore it can be used to generate quantitative output data on various parameters that influence a business system performance. Output Data Analysis, Experimental Design, and other techniques can be employed to ensure a significant degree of mathematical robustness at every stage of a simulation project.

Stochastic Modelling: Statistical representation of real-world uncertainty is an integral part of simulation models. Indeed, simulation is perhaps the most suitable modelling technique regarding its ability to capture the dynamic and stochastic behaviour of real systems. Sensitivity Analysis for example can be employed to assess a simulation model's validity with respect to variations in the values of (unknown) system parameters.

Model Documentation: The development of a simulation model requires certain assumptions about the real system which can be documented as the model is being developed. Therefore, documentation of simulation models can be a relatively easy task. However, users in practice do not always pay enough attention to the documentation process. Simulation packages which allow for automatic documentation of models can prove particularly useful for this purpose, although they cannot entirely replace the modeller's role.

Model Adaptability/Reusability: Simulation models can easily be updated to reflect changes in real world processes. With respect to BPM, a great opportunity exists to integrate workflow capabilities in simulation environments to support not only the modelling and redesigning exercise, but also the actual carrying out of business tasks, thus resulting in highly flexible and continuously reusable models.

Objective-driven Modelling: Due to their flexibility, simulation models can be customised to serve multiple purposes of management. Modellers can specify alternative output measures and apply different output data analysis techniques to simulation models, thus allowing for multiple uses of a single business model according to management requirements.

Feasibility of alternative designs: Simulation as a process is meant to help with identifying appropriate solutions to complex decision problems. The feasibility of alternative designs in a business context is essentially a step that has to be built into the assumptions made during model development. If certain managerial, legislative, or other restrictions occur, they should be taken into account during the experimentation phase by adhering to these assumptions. In this way, 'political' requirements can be easily accommodated by simulation models.

Communication of Models: Simulation models, especially when combined with graphical, animation, and/or interactive characteristics are probably the best means of communicating the essence of a model to managers and decision makers.

User Friendliness: Simulation models for business process analysis can be as friendly as their developers choose them to be. In general, simulation allows for a great degree of user friendliness (e.g. through graphical user interfaces) which is supported by the majority of existing simulation packages.

In the next section we will concentrate on inter-organisational business settings and try to understand the characteristics of inter-organisational business processes, to identify additional modelling requirements, and to assess the potential of simulation in this context.

3 INTER-ORGANISATIONAL BUSINESS PROCESSES: CHARACTERISTICS AND ADDITIONAL MODELLING REQUIREMENTS

3.1 Characteristics of Inter-organisational Processes

Problems of BPM become even more difficult to tackle when considering processes which extend beyond the boundaries of a single organisation and include multiple businesses in the value chain. Examples of such processes include purchasing (supplier involvement), shipping (when third parties are employed to transport goods), sales (customer involvement), etc. Inter-organisational involvement might exist even in processes which seem at first to be internal, but require (explicitly or implicitly) the co-operation of third parties.

A single organisation cannot control the behaviour of external parties in the way it can with its own resources (people, equipment, etc.). Therefore, the degree of uncertainty is substantially increased with possible implications for the validity of the derived models. Modelling of inter-organisational processes must be exercised with great care to avoid such pitfalls and sensitivity analysis becomes an extremely important issue in this case.

Furthermore, modelling requires extensive data collection and organisation in order to understand and structure the behaviour of the system under study. In the case of external players, such data might not be available, so businesses usually have to rely on additional assumptions that might further jeopardise the validity of the business model.

Decision making becomes extremely difficult in situations where multiple players are involved, since the decisions made by managers in one firm are affected by the (uncontrollable) behaviour of outside parties. For example, a company might decide to adopt a Just-In-Time method of production based on results derived by a, perhaps simulation, modelling exercise showing that such a strategy could streamline the company's operation, cut down on operating costs, and increase timeliness and quality of service to customers. However, the company's suppliers might not be able or willing to deliver raw material at short notice and in small quantities (an essential prerequisite of JIT implementation). If managers decide to adopt such a JIT approach and redesign the respective business processes without a prior assessment of the possible outcomes according to alternative supplier reactions, results might be unexpected. Interactions between players should always be taken into account in inter-organisational modelling and decision making.

There are cases where the decision to model inter-organisational business processes comes from all the parties involved. For example, a company might agree with its suppliers to develop a common model of their trading communication in order to identify opportunities for change. Such a case is presented in the following section. In such a setting, most of the aforementioned problems become less important, since the behaviour of all parties is generally more controlled and input data can be more easily available. The new problem that arises in this case is the multiplicity of decision making levels. When for example, two companies (Company A and Company B) develop a single model to represent their trading interface, decision making can be performed either at a single-site level (e.g. Company A experiments with the model to identify opportunities for change within its own operations) or at a multi-site level (i.e. joint brainstorming sessions of the two companies).

In the first case, the model should allow for experimentation only with those parts (sub-models) which represent processes that are performed by Company A (since A cannot control or change the processes of B), and should also allow for multiple output analyses, both at an intra-organisational level (to assess impacts of changes within the company) and at an inter-organisational level (to understand the consequences of individual decisions to the whole system, as these might influence the reactions and future behaviour of Company B).

In the second case, multi-level output analysis is again of paramount importance, since companies need to assess the impact of changes both on their individual performance and in the efficiency of the value chain as a whole.

We can conclude that inter-organisational business processes differ significantly from processes limited to one organisation. Although the requirements reported in previous sections for BPM are still valid, Inter-organisational Business Process Modelling (IBPM) requires additional considerations which will be outlined below, after presenting a small-scale case study of Inter-organisational modelling.

3.2 A Case Study Of Inter-Organisational Simulation Modelling

The work presented here was part of a wider BPR project aiming at redesigning trading communication between a major pharmaceutical company in Greece (Company A) and its main distributors. The sub-project that is described here involved the medical division of Company A which sells small equipment and medical consumables to hospitals and healthcare institutions, via a number of distributors throughout Greece. Each distributor covers a specific geographic area and is responsible for delivering products to customers from its own inventories which are replenished by the main inventory of Company A at regular intervals.

One of the problems identified by the management of Company A (due to space constraints we will be limited only to one of the areas that was actually examined in the project) was the long time it took for a hospital to receive goods from the time it had placed an order. The long lead times were causing customer dissatisfaction and their reduction was considered as a top priority by the management of Company A.

The ordering process was analysed and found to be unnecessarily complicated: Customers placed their orders *either* with Company A *or* with Company A's salesmen who visited the customer sites *or* directly to the distributors. However, all orders had to be authorised by Company A before the distributors proceeded with order execution. This policy resulted in unnecessary delays as the distributors and the salesmen had to forward the orders to Company A, which gave the authorisation (usually with no amendments) and forwarded the orders again to the distributors. Figure 1 illustrates the process.

A simulation model to represent the aforementioned ordering procedure will necessarily include activities performed and controlled by Company A (including Order Receipt, Order Processing, and Order Forward to Distributors), but also activities performed by the distributors (e.g. Forward Order to Company A), by the salesmen, and by the customers. Furthermore, certain activities require a degree of co-operation between parties, thus reducing the flexibility of individual firms to initiate changes in the respective processes.

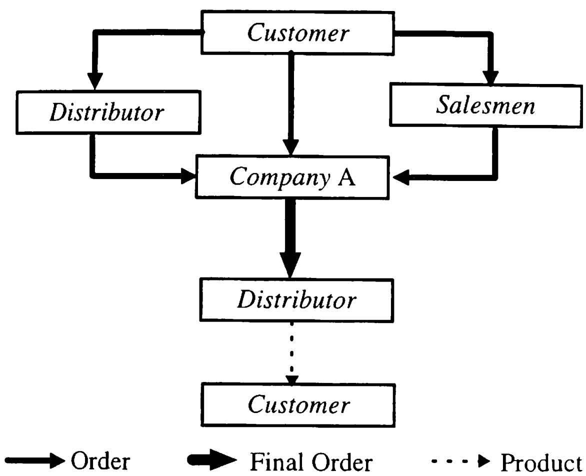

Figure 1: Ordering Process

For example, looking at the model from Company A's perspective, one might want to assess the possibility of changing the ordering process in such a way that salesmen have greater independence and can authorise orders and forward them directly to the distributors, thus relieving Company A from the additional administrative burden. If this scenario is simulated and seems to improve performance in Company A, it might still not be applicable in practice because the distributors might not accept having too many communication channels open to receive orders, as this could influence their own throughput. In this case, the burden of order authorisation in Company A is simply transferred down the value chain to individual distributors. The requirement is for a simulation model that will enable Company A not only to identify the impact of changes in their own performance, but also to measure the influence that the same changes might have on other parties (such as the distributors) in order to be able to more safely 'predict' their reaction to changes.

Another solution might be for distributors to proceed with the orders they receive from customers without waiting for an authorisation from Company A. Such a policy would surely eliminate the delay of orders delivered to distributors and waiting idle until they are authorised, thus resulting probably in reducing the overall order lead time (which is the objective of the whole exercise). However, this is again a policy that has to be implemented by a party outside of the decision sphere of Company A. Distributors might not be willing to adopt such a policy as it would mean an additional level of responsibility for them. Therefore, they have to be persuaded that such a policy would be in their interest too. How can this happen if the model used does not provide output data to assess the performance of the individual players? And what would happen if distributors wanted to experiment only with the parts of the whole model that describe their own behaviour to improve their understanding about the impact of proposed changes on them? If the simulation model is not modular and easy to decompose, they would probably have to build a new model from scratch just to represent the same workings which are already included in the initial model.

A third option for Company A and its distributors might be to co-operate in a joint effort to improve the quality of service they offer to their customers. They might, for example, want to investigate the possibility of adopting EDI to electronically exchange orders, thus reducing unnecessary delays during communications. In this case, the requirement would be for a simulation model that will allow them (a) to fully understand the interactions implied by the new way of communication before committing to changes, (b) to assess their individual performances under the new scheme, (c) to be able to measure the overall improvement in the value chain in terms of total order lead time reduction, and (d) possibly to communicate the results with their customers to persuade them to adopt EDI as a means of order submission as well.

Surely, there are a lot of alternative ways to implement the ordering process in a way that can fit Company A's management objectives. These ways need to be modelled keeping an eye on the influence changes might have on the performance of individual players as well as the whole system. Such a level of modelling and analysis cannot easily be implemented with existing simulation packages, as it requires modular model design and multiple levels of output analysis.

A way to overcome the modelling problems would be to use a general purpose programming language to implement a modular model. An approach is to implement each player (customers, distributors, salesmen, and Company A) as an independent sub-model. Each sub-model communicates with others when necessary (for example when an order is forwarded) via a message passing mechanism which initiates the creation of an entity in the TO model, while it places the respective entity in an idle state in the FROM model. For example, when distributors forward orders to Company A for authorisation, orders remain idle in the distributor submodel, while a 'new' order is created in the Company A submodel. When the order is authorised, it is 'sunk' in the Company A submodel and the respective entity in the distributor submodel becomes busy again (forwarded to be processed).

Although this message passing mechanism facilitates 'independent' modelling of the various levels of decision making of the system and allows for output analysis of submodels, the whole process is clearly not user-friendly and cannot provide the necessary degree of adaptability and reusability required for business models. A far better solution might be to use a user-friendly simulation package for model development, provided that a package to satisfy the aforementioned requirements actually exists on the market.

3.3 Additional Requirements for Inter-Organisational Business Modelling

Based on the analysis of the case study presented above, we can derive the following additional requirements for Inter-organisational Business Modelling:

Modular Model Design. A holistic approach to business modelling is necessary to identify implicit interdependencies among processes, even when they are performed by different organisations. On the other hand, different parties should be able to use suitable sub-models to assess their own performance (but, at the same time, keeping an eye on the influence of 'local' changes on 'global' performance). There is clearly a need for modelling conventions that will allow for modular model implementation and for experimentation with selected sub-models.

Modular Model Analysis. Models that represent the workings of more than one business unit should also allow for a multi-level output data analysis to accommodate the decision making needs of the individual parties involved as well as any of their combinations. Business process configurations that are derived from these models should optimise the performance of individual firms and, at the same time, streamline the efficiency of the whole system. Improvements achieved by individual players should not be lost downstream or upstream in the value chain.

Model Decomposition and Integration. Implementation of modular models should be achievable even if this is not the initial target of the modelling exercise. For example, two firms might develop models independently of each other and at a later stage wish to link these models into a concrete inter-organisational model. To enhance model reusability, individual models should be easy to link, without extensive modifications. In the same way, a single model might need to be decomposed to sub-models, when for example departments of an organisation need to assess their individual performance. Perhaps the only way to achieve problem-free model decomposition and integration, is by defining standard interfaces between models.

3.4 Simulation as a Tool for Inter-Organisational Business Modelling

Simulation models have the potential to become powerful tools for modelling inter-organisational business processes. However, in contrast to intra-organisational simulation, existing commercial products do not generally provide the necessary functionality to meet the requirements identified above.

Modular Model Design: Although simulation as a technique can theoretically be used for modular model development and use, existing simulation packages do not generally include such characteristics. At the time being, the requirement for modular model design can only be met if a general-purpose programming language or a simulation programming language is used to develop the model. We are aware of no existing simulation packages (i.e. software that allows model development and use without or with very limited programming) that include advanced functionalities to assist the user in modular model design. This does not mean that modular model development cannot be done with simulation packages. Rather it means that the user is left alone in performing this task, i.e. the package does not guide him/her towards defining appropriate sub-models that will *clearly* indicate the 'decision territories' of the firms involved in modelling.

Modular Model Analysis: Things become even more difficult when considering the issue of analysing inter-organisational models for the purpose of decision making. Again the problem seems to be that existing simulation platforms do not provide multiple levels of output analysis. Even worse, in the majority of cases output analysis is not provided at aggregate levels at all, and is usually limited to performance indicators within single functional units of the model (resources, activities, or queues). This however, cannot satisfy the requirement for assessing whole, inter-function extended, business processes which is usually needed in business change projects.

Model Decomposition and Integration: At the current status of non-existence of industrial standards to define the interconnectivity issues between simulation model components, this requirement cannot be easily satisfied. Only if individual models are developed on the same platform, can they be connected in a relatively painless way. If different simulation environments are used, then model integration is usually simply not possible, and a new model should be developed from scratch. Regarding model decomposition, things are slightly better since a single model can always be truncated to include only a subset of its initial range. Even in this case however, the user will probably need to carry out sub-model definition, to define new output analysis measurements, to 'fill' gaps generated by model truncation, etc.

4 DISCUSSION: THE ROAD AHEAD

Business process modelling carries several distinct characteristics that differentiate it from other types of modelling problems that simulation has been traditionally used for. This highlights the need for a focused approach to the development of software packages for business process simulation.

The requirements identified in this paper are basically meant as guidelines for prospective users or developers of business simulation models. Of course, each individual requirement carries a different weight depending on the objectives and characteristics of a particular change management project.

Two avenues for further research can emerge from the aforementioned analysis. The first refers to the development of a formal framework to explain the characteristics of business modelling and assess simulation under a variety of practical business problems. The second refers to a more holistic concept that might be necessary for an integrated approach to business modelling. This approach should combine simulation modelling with other computer-supported modelling, experimentation, and decision making tools in an effort to integrate business process modelling (as part of a redesign exercise) with business performance monitoring (as part of the actual carrying out of business tasks). Computer Aided Business Modelling and Monitoring (CABMM) can be the next target of applications to integrate Simulation, Expert Systems, Workflow Software, and internal business applications in an effort to institutionalise process modelling and measurement in modern businesses.

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