A STUDY OF THE IMPACT OF INFORMATION TECHNOLOGY ON BUSINESS PROCESSES USING DISCRETE EVENT SIMULATION: A REPRISE

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Abstract: Advocates of Business Process (BP) approaches argue that the real value of IT is that it provokes innovative changes in business processes. Despite the fact that many BP and IT academics and practitioners agree on this idea, BP and IT design are still performed separately. Moreover, there is very little research that is concerned with studying the ways in which IT supports BP. The ASSESS-IT project examined this domain and proposed the use of simulation techniques to achieve BP and IT integration. The outcome of this project gives indication that describing the dynamic behaviour of IT could be very helpful for BP modellers in predicting the impact that the insertion of IT may have on organisational processes. This paper describes the rationale of the simulation framework used in the ASSESS-IT project and analyses the results obtained when applying this framework to a case study in order to reflect about the advantages and limitations of this approach and to identify possible areas for further research in this domain.

Keywords: Business Process, Simulation, IT

1. INTRODUCTION

Business processes (BP) became the focus of continuous improvement efforts in the mid-40's [Davenport and Stoddard, 1994]. It is argued, however, that process analysis started far before in 1911, when Frederick Taylor first advocated the systematic study of work procedures. From that time, the concept of process became very important. For example, process control and process techniques have been outlined in the quality movement [Juran, 1964; Garvin, 1988]. Process skills and process consultancy have been very important in human relations and management of change schools [Schein, 1969]. Operations management is concerned with the management of processes, people, technology, and other resources in the production of goods and services [Armistead et al., 1995].

It was at the beginning of the 1990's when the process movement became very strong. Business Process Reengineering (BPR) also named Process Redesign, or Process Innovation is one of the most popular concepts in business management [Davenport, 1993, Hammer and Champy, 1993, Kettinger et al., 1997]. The study of business processes, however, is not isolated and has always been related to Information Technology (IT). IT is considered one of the most important enablers of process change. In one of the first articles about BPR, Davenport and Short [1990] argue that together, processes and information technology can be seen as a new industrial engineering that may revolutionise the way in which organisations operate. Similarly, Hammer and Champy [1993] claim, in one of the most renowned books on BPR, that IT is part of any reengineering effort, and they position IT as "an essential enabler".

Most of the advocators of the business process reengineering movement highlight the importance of the role that IT plays in the reengineering process. Many argue that IT should be seen as an enabler of organisational change rather than as a tool to implement business processes [Davenport, 1993]. Childe et al. [1994], for example, state that the initiative to move towards BPR in many cases originates from the IT departments. In one of the first empirical studies on IT-enabled BPR, Grover et al. [1994] claim that the success of IT to enable BPR lies on IS-strategy integration. They contend that the success of IT-enabled BPR efforts will succeed only

if they are directed through a strong integration with strategy.

This relationship, however, is not fully explored in most of the existing business process methodologies. To illustrate this point, let us consider two BPR approaches proposed by Davenport [1993] and Kettinger [1997].

Davenport's [1993] framework identifies Information Technology as one of the three main enablers of business change and provides a detailed picture of how IT provides opportunities of change and advocates that the design of IT should be done together with the business processes. The major contribution of Davenport's [1993] framework is that it is one of the first BPR efforts that attempts to co-ordinate process and IT design and gives sufficient evidence to help identify different ways that IT can be used to improve process performance. A major limitation is that despite the fact that this framework points towards what needs to be done and where, it barely mentions how to do it.

Davenport acknowledges that the tools and techniques for achieving process objectives are distinct in use from those for developing information systems. Despite this fact, however, he advocates that IS requirements and data structures should fit with the corresponding business processes, and that the implementation of IS should be closely co-ordinated with corresponding process implementations efforts. In an attempt to help in this direction, the author outlines extant technologies that can play an important role in the implementation of processes. Davenport's framework, however, does not supply information that indicates how to study the IT impact on BP.

The role of Information Systems in enabling change is pursued in more detail in the S-A framework in Kettinger et al. [1997] work. The S-A framework specifies an activity (S4A4) to analyse and design IS, and other activity (S5A2) to implement IS. The framework in this paper clearly specifies modelling techniques and tools that can be used in each of the S-A framework stages and activities. Despite this fact, the S-A framework has a similar problem to Davenport's framework: it focuses almost entirely on identifying techniques and tools that can be used in each of the stages and forgets to mention how the co-ordination between process and information techniques can be achieved. Although the identification of modelling techniques for process and information system design is more detailed, there is no integration between process and IS modelling techniques.

One of the few papers that address the integration of BP and IT modelling domains, is presented in Painter et al.'s work [1996]. The authors argue that despite the fact many people advocate conducting BPR and Information Technology modernisation efforts in a highly co-ordinated fashion, there has been little success to date in achieving this attempt.

To address this problem, Painter et al. [1996] propose a simulation-based methodology, named BPR-II, for change impact assessment, enabling simultaneous consideration of changes to business processes and the infrastructure mechanisms that support those processes. They argue that the BPR-II methodology and an accompanying automated support environment will provide the ability to link models of both, business process and the supporting IT infrastructure.

Painter et al. [1996] propose the insertion of a 'middle' layer between BP and CN which consists of models that depict the IT applications that run on the CN and support the BP (Figure 1).
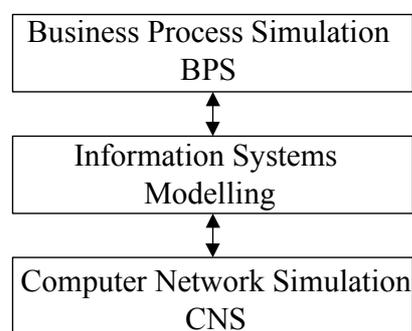

Figure 1 BPS and CNS Integration (derived from Painter et al., 1996)

The authors propose the use of the IDEF3 Process Description Capture method as the key mechanism for process knowledge capture and organisation. IDEF3 process descriptions are used in this methodology to capture a definition of the process at all three levels, namely business process, application and network processing, and to directly generate the structure and logic of simulation models reflecting these levels.

Probably one of the major contributions of Painter et al.'s [1996] paper is that it recognises the need to integrate process and information technology design and identifies an intermediate layer, information systems, as the link between process and computer networks. The approach, however, has some limitations. IDEF3 is a modelling technique that can be used to depict how a particular system or organisation works. IDEF3 however, is not very appropriate for process change initiatives, as it offers very limited capabilities to portray the organisational and behavioural perspectives. Moreover, the tools to derive BP and IS models from IDEF descriptions do not necessarily produce a final integrated model and further design and development may be needed towards this integration.

Another possible disadvantage of this methodology is that in order to achieve model integration it

produces an elaborate net of models with a high level of complexity, which in a large exercise would be almost impossible to follow. Other BP simulation tools, such as Business Process simulation (BPS), have proved to offer a friendlier user-environment that makes the elaboration of BP models simpler than the one proposed in this paper. Finally, IDEF3 is a static technique whereas simulation is a dynamic modelling technique. Data interchange between dynamic and static techniques adds another degree of complexity.

Despite the fact that both process design and information systems approaches argue that IT plays a key role on process and IT design, most of the BPR approaches do not provide any clear guidance of how this could be achieved, or any indication of which modelling techniques could be used to detect how IT supports organisational processes.

Painter et al's work suggest that it is very unlikely to find a single modelling tool that would help to model process and IT interactions. A major problem of the approach proposed in their work is concerned to the modelling techniques suggested, since they may not be appropriate to cope with the problem, mainly due to the diversity of the techniques used (dynamic and static).

This paper describes a modelling approach that aims to combine business process and computer network simulation (CNS) to portray the interactions between process and IT. The approach attempts to provide a solution to the problem of measuring the impact of IT on BP and is tested using a case study. The paper is divided into 5 major sections. Section 2 briefly revises discrete event simulation, and in particular, Business Process Simulation (BPS) in order to justify the use of this technique in our approach. Section 3 is an introduction to the case study. It describes the case study background, the scope and objectives of the case study, the problem identification phase, and finally, explains in detail the as-is business processes. Section 4 describes the method proposed to model the interactions between BPS and CNS. Section 5 reports the experiments performed and the results obtained. Conclusions and further research are described in section 6.

2. MODELLING PROCESS AND INFORMATION TECHNOLOGY USING DISCRETE EVENT SIMULATION

Discrete-event simulation (DES) can be described as a technique that is concerned with the modelling of systems in which the state variable (the collection of variables necessary to describe the system at any time) changes only at discrete points in time [Banks et al., 2000]. It is in these points at which an event occurs, where an event is defined as an instantaneous occurrence that might change the sate of the system [Law and Kelton, 2000]. Both authors argue that despite the fact simulation can be, in principle, performed by hand calculations, the number of calculations that are needed to model real-world systems are considerably high and therefore discrete-event simulations are mostly designed with the aid of a computer system.

Discrete-event simulation has been largely used by operational research and system analysts. The circumstances under which simulation is considered an appropriate tool have been discussed by many authors [Naylor et al., 1966, Banks et al., 2000, Law and Kelton, 2000] and are included in the following list:

- Simulation enables the study of, and experimentation with, the internal interactions of a complex system, or a subsystem within a complex one. By changing simulation inputs and observing the resulting outputs, valuable insight may be obtained into which variables are most influential and how variables interact.

- Informational, organisational, and environmental changes can be simulated and the effect of these alterations can be observed.

- A simulation model may be of great value to suggest improvement in the system under investigation.

- Simulation can be used to experiment with new designs or policies before implementation to prepare for what may happen.

- Simulation can be used to verify analytic solutions.

Discrete event simulation is one of the modelling techniques most commonly used in the process domain. The following list includes the views of some authors [Gladwin and Tumay, 1994, MacArthur et al., 1994, Warren et al., 1995, Hlupic and Robinson, 1998, Giaglis, 1999] that consider simulation as an appropriate tool for business process re-design.

- Simulation provides ways to model the dynamic behaviour of business processes.

- Simulation can be used to model, in a more realistic way, the randomness, uncertainty, and interdependencies of resources.

- Simulation can help to contribute to understand and improve the analysis and study of the inherent complexities of business process.

- Simulation can be used to assess the potential value and feasibility of alternative process designs.

It can be said that simulation is one of the modelling tools that are able to overcome some of the limitations found in static modelling techniques. Static modelling tools produce deterministic models

which are independent of process sequence, therefore, they do not enable the evaluation of alternative process [Hlupic and Robinson, 1998]. Simulation, on the other hand, is able to model the dynamics of the process (system behaviour).

The fact that simulation has been successfully used in the process domain positions this technique as one of the most suitable candidates to address the business process and information technology integration problem defined before. Additionally, the circumstances under which simulation is considered an appropriate tool fit naturally to the description of the previous mentioned problem.

The approach described in the following sections aims to overcome the limitations found in current approaches by using simulation throughout the analysis and design of both business process and information technology. To this end, the approach proposed in this paper uses business process simulation to address the organisational and informational views and a computer network simulation model to measure the impact that IT may have on the business processes.

3. CASE STUDY

The case study presented here consists of two collaborating organisations in Greece. One company is a branch of a major multinational pharmaceuticals organisation (we will refer to this company as 'Org-A'), while the other is a small-sized regional distributor of Org-A's products (we will refer to this company as 'Org-B').

The case study to be analysed in this paper was carried out within a single business unit, which deals with hospital consumables. Its major customers are, mostly, relatively large public sector organisations, such as hospitals, health care organisations, networks of physicians, and the government. The business unit does not produce products but imports them from other Org-A production sites across Europe. The goods are stored in a warehouse that operates as a central despatch point for all products, which are then distributed to the company's customers via a network of collaborating distributors. One of these distributors is Org-B.

Org-B is a small company that has signed an agreement to act as Org-A's exclusive distributor of Medical unit products. The agreement that Org-B's responsibilities include:

a) Receiving orders from Org-A customers.

b) Maintaining an adequate inventory of products that fulfil the orders.

c) Distributing the ordered products to customer premises.

3.1 Scope and Objectives of the Simulation Exercise

Due to the nature of the products, Org-B, as the company in charge of delivering products, has to operate within rigorous deadlines. The agreement between the companies, stipulates that each order has to be fulfilled within 24 hours for products delivered within the city of Thessaloniki, or within 48 hours for the rest of northern Greece.

Org-A management has noted, however, that these targets are rarely met in practice. A brief analysis by the companies seemed to attribute the problems to some inefficiencies within the ordering system as well as difficulties being experienced by Org-B in maintaining their inventory at an optimal level. In addition to this the communication system between the two companies was also seen as slow and cumbersome. The effects that these inefficiencies caused were seen as a major source of customer dissatisfaction, so an in-depth analysis of the problem was commissioned. The main objectives of this study were:

a) To examine the existing business processes that were felt to be responsible for long lead times for order fulfilment.

b) To determine the sources of problems and propose alternative solutions.

c) To evaluate the potential of introducing appropriate IT to improve communication between the two companies.

3.2 Problem Formulation

As stated before, business process and computer network simulation techniques will be used throughout the case study. According to Banks et al. [2000] and Law and Kelton [2000], any simulation exercise should begin with the definition of the problem.

This sub-section presents the problems that Org-A and Org-B managers identified after a series of discussions and a brief analysis of the current processes.

a) Excessive Order Lead Times. Orders were fulfilled much slower than the agreed targets of 24 and 48 hours (see section 3.1). This problem is intensified by the fact that the levels of stock in Org-B's warehouse are not appropriately maintained and in many cases, a back order has to be placed which in turn, lengthening the overall order fulfilment time.

b) Inappropriate inventory replacement policy. To try to reduce the number of backorders, Org-A warehouse managers implemented a generous replenishment policy for Org-B's warehouse. However this has caused considerable holding costs for Org-B as well as problems arising due

to sensitive medical products reaching their expiry date.

c) Poor customer service. Due to the problems outlined above, a considerable rise in the number of customer complaints, regarding delivery delays, were received.

d) Excessive Invoice Lead Times. The time it takes for invoices to reach customers is unnecessarily long, resulting in poor cash-to-cash cycle for both Org-A and Org-B.

e) Data and Work Duplication. Org-A need to know the Org-B's stock levels in order to plan and schedule replenishment shipments. Org-B's send their stock levels (not electronically) to Org-A. This results in duplication of work (double typing the same information), and on many occasions the data reported in Org-B and Org-A systems do not match.

f) Information Sharing. Org-B and Org-A information infrastructures are incompatible. Consequently, the companies have to rely on paper forms to share information, which in turn causes duplication of data and effort, as well as slow processing times.

It has been identified that one of the major contributors to the problems faced by both organisations was related to the information technology infrastructure. It was found that both, Org-A and Org-B IT infrastructure was incompatible, poor, or in some cases non-existent. The two companies then, decided to investigate the potential of using a new IT infrastructure to facilitate information exchange.

Both organisations propose to analyse the introduction of Electronic Data Interchange (EDI) in order to provide faster and more reliable exchange of information. It was believed that EDI would contribute to managing the inventory more efficiently helping in this way to reduce the backorders, eliminate work duplication and data errors, standardise IT infrastructures in both companies, and finally to share information in a more efficient manner. Consequently, order and invoice lead times were also expected to be reduced.

4. SIMULATION APPROACH

The simulation exercise presented here focuses on investigating the suitability of using discrete event simulation models to assess the impact of the insertion of EDI in Org-A and Org-B. To this end, two discrete event simulation techniques were selected to model both business process and IT: BPS and CNS.

CNS was selected because two major reasons. First, it is one of the most popular discrete event simulation techniques to model computer networks,

and second, it recently offers capabilities to model software applications.

Based on the literature review and on the steps for a simulation study suggested in Banks et al. [2000] a simulation framework to assess the impact of new IT in a BP model was proposed, namely ASSESS-IT simulation framework. The following steps are a résumé of each of the steps suggested in Banks et al. [2000]:

1. Problem formulation. A statement of the problem should be the starting point of every study. Policymakers and the analyst should sit together and agree on the formulation of the problem.

2. Setting of objectives and overall project plan. The objectives will indicate the questions that the simulation model should address. The overall study should be planned in terms of the number of people, the cost and the time needed for each aspect of the study.

3. Model conceptualisation. Although there are not many firm rules about how to design the simulation model, most of the authors are in agreement that it is always better to start with a fairly simple model of the system, which can be later be made more sophisticated if necessary.

4. Data collection. In this phase the available data of the system in question is collected. This in turn should be used to specify operating procedures and probability distributions for the random variables used in the model. If possible data on the performance of the system should be collected for validation purposes in step 6.

5. Model translation. Due to the complexities of the systems that are being modelled, most simulation is performed by computers. This means that once the model has been designed and the data collected, the model must be converted to a computer program. This is usually done through an appropriate simulation package.

6. Verification. When programming the model it might be necessary to generate random variables from specific probability distributions. For further references in relation to the techniques to generate these numbers as well as for verifying and debugging a computer program see Law and Kelton [2000].

7. Validation. Pilot runs can be applied to test the sensitivity of the model. If small changes to the input parameters have significant variations on the output a better estimate of the input parameters must be done. If the model was derived from an existing system, the results obtained from the pilot runs can be compared to those outputs from the actual system. Once the

model has been "validated" as a good representation of the system under analysis, then the experimentation process can begin.

8. Experimental design. This phase determines the alternatives that are to be simulated. For each system design to be modelled, decisions have to be made on issues such as initial conditions for the simulation run(s), the length of the warm up period (if any), the length of the simulation run(s), and the number of independent simulation run(s) (replications) required for each alternative.

9. Production runs and analysis. Production runs, and the following analysis are made to provide performance data on the system designs of interest.

10. More runs? The analyst should determine, based on the information collected in step 9, if

additional runs are needed as well as the design that those experiments should follow.

11. Document, present, and implement results. Because simulation models are often used for more than one application, it is important to document the assumptions that went into the model as well as the computer program itself.

12. Implementation. When implementation of simulation studies ends in failure, this is largely due to the credibility of the model. Those models in which the user has been deeply involved throughout the design and testing stage are much more likely to be successful.

The approach proposed in this paper is based in the above framework. The new approach adapts Banks' framework in that it can be used to design BP and CN models and share information between them (see Figure 2).
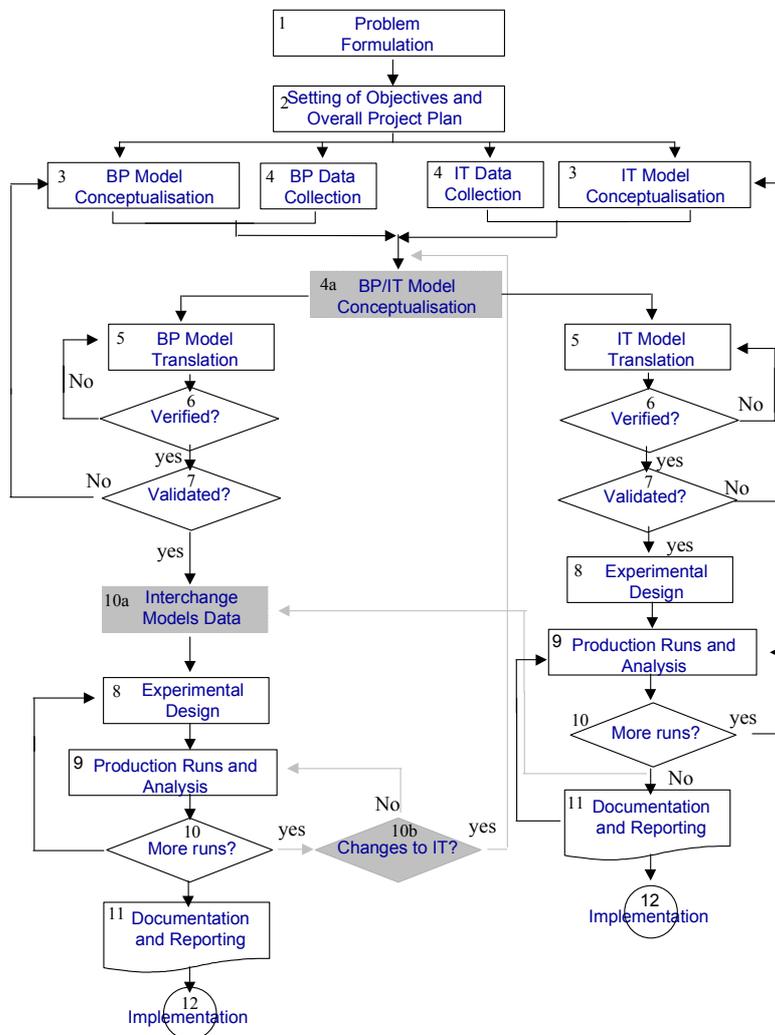

Figure 2 ASSESS-IT simulation framework (based on Banks et al. [2000])

The framework aims to build a computer network model of the proposed IT and feed the outputs from this model into the business process model. The model results would then reflect the changes that the new IS/CN would produce at the BP level. To this end we proposed the following changes (grey coloured in Figure 2):

1. The *Problem formulation* and *Setting of objectives and overall project plan* should be performed together for both business process and computer network models.

2. Model Conceptualisation and Data collection steps should be performed separately for both BP and CN models.

3. A new step *BP/IT model conceptualisation* (4a) is introduced. The aim of this step is to co-ordinate the conceptualisation of the BP with the CN models and vice versa so they reflect both process and information technology.

4. Steps 5,6,and 7 are performed as suggested in the previous framework for the BP model. As for the CN model the next steps follows the framework suggested in Banks' framework.

5. A new step (10a), *interchange models data*, is introduced in The BP model steps. Before going to experimental design step, the BP modeller should wait for the input from the CN model results (e.g. transmission times over the specific network conditions), which are to be considered for the experimentation design phase.

6. If more runs are needed in step 10 in the business process model another decision needs to be made (step 10b). If the decision in the business process implies changes to the IT, both models need to start at the step 4b, otherwise the BP steps continues normally. It is expected, though, that changes to the models will not be of great significance. Therefore, the following steps should be completed quicker than in the first round.

Considering the framework described above two models of the previously described case study were built. One that reflected the activities at the business process level, and the other that represented the new computer network and IS systems that was to be installed to support the processes. The following section describes the experiments that were made together with the results they produced.

5. EXPERIMENTATION AND RESULTS

5.1 Problem Analysis

Models of the case study described previously were designed. As the existing system had no supporting IT infrastructure, the original models were designed based solely on the business processes. The model was run and the results analysed. The findings confirmed the concerns of the companies that delivery times were much longer than the agreed targets. Even when no backorder was required deliveries to Thessaloniki took 32 hours (target time was 24 hours), while deliveries to the rest of northern Greece took 57 hours (target time was 48 hours). This gave an overall average time of 45 hours for orders that were in stock. However, when we included those orders that had items that were out of stock the average time to deliver the entire order rose to 85 hours. From these figures it was apparent that the backorders were causing some severe problems, so we analysed these a little more closely. Any order that required some out-of-stock products would effectively result in the order being divided into two separate orders, those products that were available, and those that were out-of-stock. The available products would be delivered as soon as possible, but the out-of stock products would need to be ordered from Org-A, who would then add them to the next scheduled warehouse replenishment delivery, resulting in long delays from the order being submitted and the particular products being delivered. Times were recorded for those orders that required a backorder, with the average time for the entire order (both in-stock and out-of-stock products) to be delivered being a staggering 225 hours. When this figure was analysed even further it was found that the time taken from the backorder being generated to delivery accounted for 204 hours. These results provided us with fairly conclusive evidence of where the problems lay.

5.2 Proposed solutions

One of the first points we noticed that may be contributing to the excessive delays in fulfilling backorders, was that the backorders were being generated by Org-B and then held until the Friday evening, before being sent by post, which takes 2 days, to Org-A. For the purposes of analysis the solution proposed was split into two different scenarios. First, we looked at the scenario where there were no changes made to the actual process, only that the backorders were faxed to Org-A instead of sent by post. It was assumed that by reducing the time the backorders spent in the mail system would have a substantial impact on the delivery times. The second part of the proposed solution concerning backorders, was that instead of waiting until Friday to forward the backorders to Org-A, the orders would be sent on, by fax, as soon as they were generated. It was thought that this would have an enormous impact on the delivery times, as a backorder that was generated on a Monday could now be actioned immediately, rather than being delayed until the Friday before being forwarded.

Two other solutions that would possibly alleviate the problems with backorders were also considered.

Org-A sends a lorry to replenish Org-B's warehouse once a week. A scenario where the replenishments were despatched twice a week was designed. A final scenario where the two companies share the same database to allow Org-A to have up-to-date information on stock levels at Org-B, and hence adjust replenishment shipments accordingly was also designed.

5.3   Model Development

The aim of this paper is to analyse the outcomes reported from the case study in order to identify the advantages and limitations of the ASSESS-IT approach. For details about the development of the business and computer network models refer to Giaglis et al. (1999) and Serrano et al. (2000).

5.4   Results

The results obtained from running the initial scenario, where the back order was faxed rather than sent by mail to Org-A, were surprising. Although the time taken to send the back orders by mail was reduced from 2 days to a matter of minutes, the reduction in time taken to deliver the entire order was reduced by only 15 hours. However, when we consider that it is only the back orders that are affected, the results look more understandable with an average reduction of 55 hours in the time taken from ordering to delivery.

The second scenario produced some even more surprising results. Faxing the back orders to Org-A as soon as they were generated actually increased the time taken from ordering to delivery of back orders. What had been expected was that this would substantially reduce the time taken, but in fact the opposite was true. This therefore resulted in a deeper analysis into this situation. One of the reasons that this was occurring was that although Org-A was receiving the back orders much sooner, they were still waiting to be dealt with until the scheduled replenishment was due. Once the replenishment order was due to be created, the responsibility for creating the back order list had changed to Org-A. The scheduling of this task was at the end of a week, but due to a lack of resources to begin the task on time, sometimes the back orders would be delayed long enough to actually miss the despatching of the replenishment order. This indicated that either this task needed to be scheduled earlier, or it needed a higher priority rating, to ensure that the orders would be included in the replenishment despatch.

The third scenario mentioned above was to schedule the replenishment shipments to be sent twice a week instead of once. This resulted in a reduction in delivery times, but it was much smaller than anticipated (5 hours for entire orders and 23 hours for back orders). The reasons for this are discussed in section 5.5.

The fourth scenario addressed the only real IT-based solution, which was that the two companies shared a database, giving Org-A a better idea of the replenishment requirements of Org-B. As was expected with this scenario there was no noticeable reduction in the delivery times of the in-stock products, but those products that required back orders showed a reduction of 31 hours. This however was mainly due to the fact that the backorder list would no longer need to be created, as it would be generated in conjunction with the normal replenishment shipment.

The results for the average delivery times of the entire order, and the average delivery time of backorders for each of the scenarios described are shown in Figure 3.
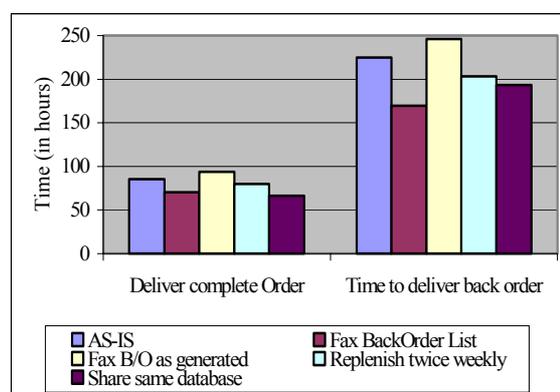

Figure 3 Average delivery times for orders and back orders

5.5   Discussion of Results

Regardless of these results the improvement was not as great as expected. When the results were studied to a greater depth, it was seen that although steps had been taken with the scenarios that would address the fact that there would be less back orders there was no way to determine the scale of the reduction. This was especially the case with the third and fourth scenarios. This led us to look at the back order situation more closely. After running the fourth scenario at various different levels of back orders, it became apparent that in order to get a reliable model that accurately indicated how back orders would be affected under various different scenarios and conditions, it was necessary to predict the behaviour of the IT that supports those processes. The level of abstraction in the business process model cannot provide these requirements.

In order to model the back orders a computer network model of the fourth scenario was designed in accordance with the framework described in section 4. One of the first aspects that had to be addressed was the fact that the computer network would be dealing with the individual products within the database, rather than complete orders. For example, the number of orders that produce

backorders doesn't indicate how many of the products from each order are missing. At the business process level, the fact that an order produces a backorder is all that is relevant. However, at the computer network level, the number of products are out-of-stock in each order affects the traffic in the communication links, which in turn affects the speed at which the information can be communicated between different aspects of the system. In order to interchange data between the models the business process model would also have to address the problem at a similar level of abstraction, or the computer network model would need to combine the various products, and customer information into a higher-level entity of an order. Due to restrictions within the computer network simulation software, it was decided that the business process model would be designed at the product level. The two models were then designed in parallel, as the points where the data would be interchanged between the models necessarily had to be measured from the same start and end points.

Other considerations that need to be taken into account when designing the models are discussed in other papers by the same authors, and are therefore not raised here (for more information look at Giaglis et al., 1999, Serrano et al., 2000).

The computer network model was run at various levels of network utilisation, and the results recorded. The reason for testing the computer network model under different levels of utilisation was that the model had been designed solely with the information obtained from Org-B. However, as Org-A is an international company, and deals with many other companies, the demands on their IT infrastructure could be quite high. This was information that was unavailable, and therefore tests needed to be performed at various levels of utilisation. It was found the effect that network utilisation had on system performance could be quite marked at extreme levels. This means that only when the network utilisation reached more than 70%, the overall network performance was affected. It was decided then to disregard levels of utilisation less than 70% and observe the effects that the processes will have when network utilisation reached more than 70%. Data pertaining to these experimentation results were then incorporated into the business process model, which was then run and results recorded.

Experimentation with the models indicated that back orders could be reduced by the introduction of IT, but the complexity of the models was greatly increased. For example, in order to depict the CN and IS behaviour it was necessary to collect more data than the one it was available from the business process model. Data related to information contained in an order, such as date of issue, number of products ordered in each order, number of items ordered for each product was required to model, as accurately as possible, the new computer network and IS infrastructure. It is necessary to develop further experiments to observe if the efforts to create such models can be balanced against the information that can be gained from the model runs. Our experiment showed that only at high levels of computer network utilisation the network performance could be affected. These levels of utilisation, thought, are extremely difficult to reach in normal network conditions.

6. CONCLUSIONS AND FURTHER RESEARCH

The impact of the experiments described in section 0 was not evident until the number of backorders produced was reduced. This reduction was not seen as the primary reason that IT was to be introduced, but rather a knock-on effect of more up-to-date information being available. This evidence shows that IT can change the way in which processes are performed in more ways than the simple automation that had previously been envisaged in this solution.

IT allows information to be more accessible, and better information allows improvements to be made to systems and processes beyond that of pure automation. The difficulty associated with simulating information systems, is the question of how information itself can be represented within the simulation study. As this is the most important part of an information system it is necessary to incorporate it into the design of simulation models. Designing both the computer network model and the business process model simultaneously allows for information to be passed from one model to the other, and hence the changes in the IT infrastructure to be reflected in the business process model and vice versa.

Further refinement to the approach needs to be undertaken in order to take into account the difficulties experienced due to the increase in complexity of the models, and how to incorporate other aspects of information that are of a more intangible nature.

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