Synchronous design of business processes and information systems using dynamic process modelling

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Abstract

Purpose – This paper investigates the potential of dynamic process modelling as an approach for addressing the problem of information systems (ISs) evaluation in the context of organisational change.

Design/methodology/approach – A real-life case study is discussed, showing how dynamic simulation models that incorporate the effects of a proposed IS on existing business processes can help analysts and decision makers arrive at more informed choices for system design and evaluation.

Findings – Based on the case findings, we postulate that the design and implementation of organisational systems could be augmented by the development of dynamic process models depicting business operations before and after the introduction of an IS, and the subsequent experimentation with such models to achieve maximum fit between organisational needs and system capabilities.

Research limitations/implications – The study findings imply that dynamic process modelling may be of help in the endeavour of developing ISs that are aligned with the overall business strategy and objectives.

Originality/value – Shows how dynamic simulation models that incorporate the effects of a proposed IS on existing business processes can help analysts and decision makers arrive at more informed choices for system design and evaluation.

Keywords Modelling, Process management, Simulation, Information systems

Paper type Research paper

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1. Introduction

The information systems (ISs) literature has been swamped by theoretical and practical works addressing the perennial problem of how to design and implement systems that "fit" the continuously shifting needs of organisations that need to operate within increasingly competitive and turbulent environments (Avison and Fitzgerald, 1995; Iivari *et al.*, 2000). Such approaches typically aim at increasing the likelihood of success that is associated with the "traditional" IS development paradigms that rely on the concept of the systems development life cycle (SDLC) (Avison and Fitzgerald, 1995). Such paradigms have been criticised as often resulting in IS that require extensive and expensive maintenance to remain aligned with the organisational needs. In response, a number of alternatives have been proposed. For example, prototyping (Boar, 1984) and evolutionary IS development (Arthur, 1992) aim at improving the interaction between software engineers and system users by developing limited-scale archetypes of a system before its full-scale implementation. Similarly, participative design approaches, such as Joint Application Development (Purvis and Sambamurthy, 1997) require the formal assignment of users as members of the development team to improve the likelihood that the desired functionality of the IS is specified, developed, and finally accepted by the users after implementation (Kawalek and Wood-Harper, 2002).

The need to develop ISs that can evolve and support continuously changing organisations as opposed to the traditional "fixed" investments in legacy systems has long troubled researchers and practitioners alike. In this paper we argue that this problem might stem from the "myopic" look that researchers usually adopt when looking at IS, which is concerned more with technology and less with the changing business requirements. In a world where IS introduction is usually concurrent with some sort of organisational change (for example, ERP or CRM adoption after business process re-engineering (BPR)), it might be worthwhile to investigate the concept of IS development and evaluation within the wider context of organisational change (Doherty and King, 2001).

In particular, this paper aims to explore the use of dynamic models to design informational changes and process structural changes in unison. We will argue that when such models are implemented in a simulation environment, decision makers and designers can experiment with scenarios for IS and organisational changes and investigate their reciprocal effects. The structure of the paper is as follows. First, we critically investigate current approaches to IS development and their relationship to organisational change. Second, we present an approach for IS development within organisational change projects that integrates dynamic business process and IS modelling. Third, we illustrate this approach through a real-life case study. Fourth, we analyse the case study results and reflect on their significance to the concept of IS evaluation and business process change. Finally, we conclude the paper by summarising our research findings, analysing their implications on research in IS development, and presenting some opportunities for further development of presented work.

2. IS-enabled organisational change: an overview

The term "organisational change" is used to collectively refer to the multiplicity of theoretical or practical approaches that have been proposed in recent years to assist

enterprises to plan, manage, and co-ordinate their change initiatives. Such approaches include, for example, *BPR* (Hammer and Champy, 1993), business process improvement (Harrington, 1991) and total quality management (TQM) (Crosby, 1979). Contemporary change management approaches advocate that businesses should not be analysed in terms of the functions in which they can be decomposed or in terms of the products they produce, but in terms of the key business processes that they perform.

Apart from the focus on processes, another characteristic of most modern change management approaches is the heavy importance they place on the role of IS in enabling organisational change. Many researchers (Davenport, 1993; Galliers, 1993; Giaglis, 1999; Grover and Fielder, 1994; Venkatraman, 1991) have dedicated significant amounts of work in addressing the alignment of business process change and information technology introduction in organisations. The absence of such alignment has been linked to the rather common phenomenon of IS failure (Doherty and King, 2001; Giaglis, 1999).

Davenport and Short (1990) postulate that although business process design and information technology are natural partners, their relationships have never been fully exploited in practice. Such relationships imply that organisations should align the design of ISs with the design of the corresponding business processes if maximum benefits from their synergy are to be achieved (Grover and Fielder, 1994). Although the benefits of aligning the design of business processes with the design of their corresponding ISs should be apparent in theory, such integrated design strategies have rarely been the case in practice. Structured approaches to IS development begin with an implicit assumption that the business domain issues are resolved and the system is to work in a stable and well-defined business environment, where the only issue is to identify the "correct" requirements for the new IS. As a result, not enough attention is generally being paid to investigating the interactions of the IS to be developed with the business processes it will naturally affect.

At the same time IS development is an inherently complex activity, especially when the nature of the IS is critical to the organisation and its success in the marketplace. As far as organisational change is concerned, this complexity implies that it may not be effective, or even feasible, to integrate IS development within business process change as many of the process change methods advocate.

In our opinion, the integration between business process design and IS design could be more successfully addressed by using a dynamic modelling approach that integrates both modelling of business processes change and modelling of ISs that can support the redesigned processes. Such an approach supports the concept of synchronous design of IS and business processes by enabling experiments with models of proposed business processes and IS designs to be performed before implementation. In particular, we propose to use discrete-event simulation as a dynamic modelling technique that is capable of capturing dynamic changes and the random behaviour of model components.

3. Dynamic business process modelling

The importance of the modelling process for organisational change has been heavily emphasised in the literature (Curtis *et al.*, 1992; Paul *et al.*, 1999; de Vreede and Verbraeck, 1996). The term business process modelling (BPM) has been used to incorporate all activities relating to the transformation of knowledge about business

systems into models that describe the processes performed by organisations (Scholz-Reiter and Stickel, 1996). The term information systems modelling (ISM) is used in a similar fashion to denote approaches "seeking to make our abstractions of ISs look more like the real-world systems they represent" (Sol and Crosslin, 1992).

Owing to the complex and dynamic nature of organisations, it has been argued that carefully developed models are necessary for understanding their behaviour in order to be able to design new systems or improve the operation of existing ones. However, this very complexity of business processes and IS can make modelling and experimentation an arduous and problematic task (MacArthur *et al.*, 1994), especially when there is a need to combine BPM and ISM in an integrated activity (i.e. during business engineering).

Of the BPM tools currently available, simulation seems to be offering a promising avenue for addressing the problems identified above. Shannon (1975) has defined simulation as "the process of designing a model of a real system and conducting experiments with this model for the purpose, either of understanding the behaviour of the system or of evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operation of the system". The definition of simulation reveals its theoretical potential as a tool for organisational change analysis. Indeed, simulation modelling of an organisation's processes can help towards understanding the behaviour of the existing business system, identifying problematic tasks, and making experimentation with alternative processes easier, directly comparable and less risky (Doran and Gilbert, 1994; de Vreede and Verbraeck, 1996). Examples of most widely used simulation process modelling tools include SIMPROCESS, Arena, WITNESS, ProModel and Process Charter. Figure 1 shows a typical example of a process simulation model taken from the Simul8 software package.

Regardless of the ability of simulation to address some of the issues associated with business process change in general, very little research or application has been directed towards addressing the more specific problems associated with IS-enabled process change. While business process simulation (BPS) is maturing as an application area, simulation of information systems (SIS) has only relatively recently been included in the agenda of both simulation and IS researchers (Warren, 1996). Even in the few published articles that deal with the matter (Warren and Stott, 1992), the simulation of ISs is treated at the level of technical system specifications rather than the level of organisational performance impact.

This apparent lack of research in SIS seems surprising given the importance of information in general, and IS in particular, for most contemporary business processes. The problem of IS-enabled business process change can be, as already mentioned, addressed by integrated dynamic business process/IS modelling. This approach enables investigating the impact of changes in business processes and supporting IS structure before business process changes are implemented and before an IS design is fixed and realised. We illustrate this approach in the following section by presenting a real-life case study.

4. Integrating business/IS modelling: a case study

4.1 Case study scope and objectives

The case study presented in this section was part of a wider research project, funded by the European Commission. The part of the project to which the case study refers aimed at assessing the expected operational benefits of electronic data interchange

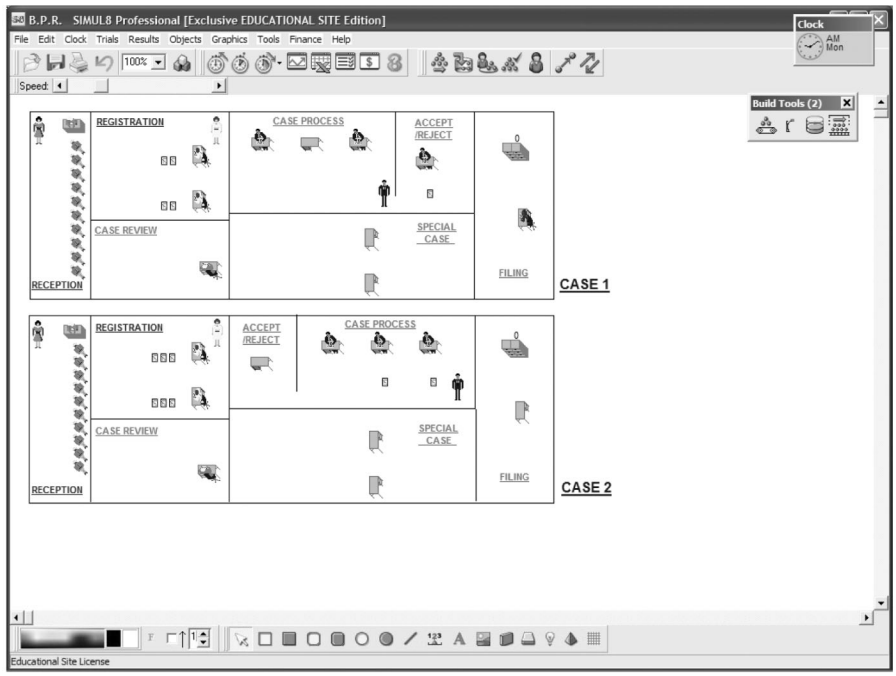


Figure 1.
A typical example of a BPS

(EDI) (Emmelhainz, 1993) in the textile/clothing sector in Greece. The main purpose of the simulation exercise was to provide tangible and quantitative measures of the alleged ability of EDI to facilitate inventory reduction in the organisations that use it as part of their ordering and logistics processes (Hall, 1994; Mylonopoulos *et al.*, 1995).

A survey of companies operating within the Greek textile/clothing sector was conducted to identify the most prevalent concerns and problems that organisations faced in their day-to-day activities. For all stages of the value chain, it was found that high inventories and their associated costs ranked high in organisations' concerns. Against this finding, it was decided to pursue a detailed investigation of the potential effects of EDI on inventories for companies operating at each individual stage of the textile/clothing value chain.

4.2 Simulation modelling approach

The main objective of the simulation study was consequently specified to provide a measure of the efficiency gains that can be achieved in inventory control within the textile/clothing value chain. It was further agreed that the simulation exercise would also attempt to examine how the existing business practices in the sector could be amended to leverage the EDI investment in order to achieve further benefits in inventory reduction. Thus, it became possible to inform the objective of studying the problem of IS design and evaluation within the context of aligning the design of IS applications with the design of business processes that these applications were intended to support.

In the absence of a context-specific theoretical or methodological approach, the generic methodology for simulation modelling advocated by Law and Kelton (1991)

was followed. Using such an approach presented the additional benefit of educating the research effort further by pinpointing potential limitations of generic simulation methods for integrated business/IS simulation. Since the objective of this paper is not to document the simulation model development in detail, but rather to focus on the lessons learnt regarding IS modelling in the context of organisational change, the main steps of the case study will be only briefly discussed in the following paragraphs.

4.2.1 Problem formulation. In line with the above discussion, it was agreed that the case study would address the potential impact of EDI on inventory reduction at all three stages of the textile/clothing industry value chain. To keep the study's complexity within a manageable size, it was also agreed that the simulation models would be confined to establishing overall estimates of EDI impact for each value chain stage, without being concerned with effects on individual companies.

4.2.2 Data collection and initial model definition. The initial model depicted the archetypal structure of the sector, as well as a set of trading rules between the companies in each stage of the value chain. Figure 2 shows the overall structure of the sector model and the detailed sub-models used (greyed areas are out of scope).

In principle, the behaviour of the companies in the model is as follows: retailers (clothing shops) satisfy customer demand for products from their existing product inventory. Inventory control is based on the processes of forecasting customer demand, order planning, and actual ordering of products to clothing manufacturers. The manufacturers also maintain product inventories to satisfy retailers' demand. Inventory control for manufacturers relies on the order plans and actual orders received by retailers, which determine the manufacturers' demand for production, and hence also the requirements for raw materials to support production. Based on their

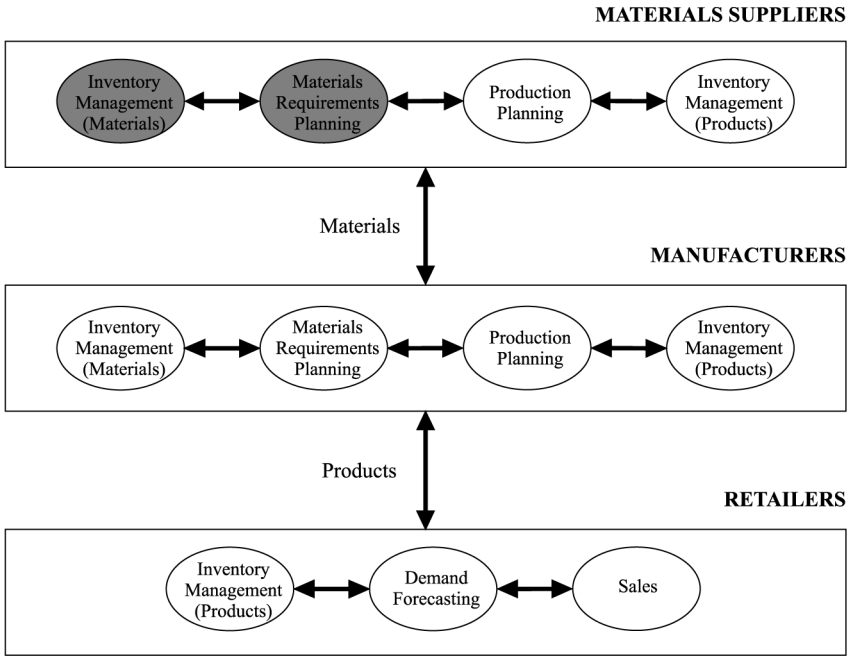


Figure 2.
The simulation model structure

production planning, manufacturers maintain a materials inventory and communicate their needs for raw materials to materials suppliers in the same way as they have received the needs for products from retailers. The materials suppliers operate in a similar fashion to manufacturers, the main difference being that their own materials inventory management has been left outside the scope of the simulation model.

The above conceptual model needed to be complemented with various exogenous parameters to provide the quantitative basis for the simulation runs. In this respect, the study benefited from the availability of a wide range of data, especially those referring to the textile/clothing sector in Greece. Such data include, but are not limited to, distributions of sizes and relative market shares of companies operating at each stage of the value chain, actual historical sales data, and so on.

4.2.3 Validation of conceptual model. Throughout the process of conceptual model development and data collection, the project team was made aware of and agreed to all modelling assumptions made by the researchers. The involvement of decision makers and the interaction with the researchers was believed to contribute to higher face validity of the conceptual model developed, as well as to greater model credibility (perceived validity).

4.2.4 Program development and verification. The elements of the initial conceptual model, together with the quantitative data collected, were encapsulated into a simulation program, which was developed using a general-purpose programming language instead of a commercially available simulator so that all intricacies and specificities of the system under consideration could be modelled without compromises. Significant attention was paid to the verification of the simulation model or, in other words, to ensuring that the conceptual model was correctly transformed into an executable simulation program.

4.2.5 Pilot runs. Pilot runs of the verified simulation program were carried out to provide the basis for model validation in the following step. The pilot runs were also used to determine other model parameters, such as the model run duration, the warm-up period, and so on. The final model was run for a simulated period of four years, the first of which is used as a warm-up period (i.e. no data are collected). The chosen run duration and warm-up period were deemed adequate for generating valid results after tests with alternative options were made.

The final deliverables of the program consisted of large amounts of raw numerical data generated in text files. Daily demand and inventory levels for each company were recorded. These data were subsequently uploaded into a Microsoft Excel spreadsheet for further processing and presentation. Microsoft Visual Basic macros were developed to automate the process of uploading and aggregating the output data to the chosen level of analysis (value chain stage – see below), as well as for generating the graphical outputs used.

4.2.6 Validation of computer simulation model. Simulation model validation deals with substantiating that a model, within its domain of applicability, behaves with satisfactory accuracy and is consistent with the study objectives. In our case, since the model depicted the operation of an existing real-world system (and the proposed changes to business processes and supporting IS), the process of validation was made slightly easier. Model validation in the case study consisted of statistically comparing the model's behaviour with additional data from the real-world textile/clothing system. In addition, data was shown to the project team for expert validation. Based on the results of the pilot runs, output data regarding the average levels and fluctuations of

product and material inventories were calculated for each stage of the sector value chain and were presented to the project team. The decision makers agreed that the simulation output data resembled, at least in terms of trends, the actual situation in the sector.

4.2.7 Experimental design. It was agreed to model two simulation scenarios. In the first scenario (henceforth referred to as the AS-IS scenario) no company in the value chain is using EDI, while in the second scenario (henceforth referred to as the TO-BE scenario) all companies at every stage are EDI users (new IS design). The first scenario represents the actual situation in the sector and was included to provide a benchmark for comparison of EDI impacts, as well as for model validation purposes. The second scenario was included to provide an indication of an envisaged "optimal" situation that could be demonstrated to the companies in the sector as part of the project's awareness activities.

In line with theoretical predictions, we assumed that the introduction of EDI in the TO-BE scenario could perhaps be beneficial for cost or error reduction, but was expected to provide only marginal benefits in terms of inventory reduction if applied in itself (Jelassi and Figon, 1994; Reekers and Smithson, 1994). In order to be able to model such effects, it was necessary to make additional assumptions for the TO-BE scenario regarding the business processes that companies would need to change to take advantage of the increased communication/co-ordination capabilities brought by EDI.

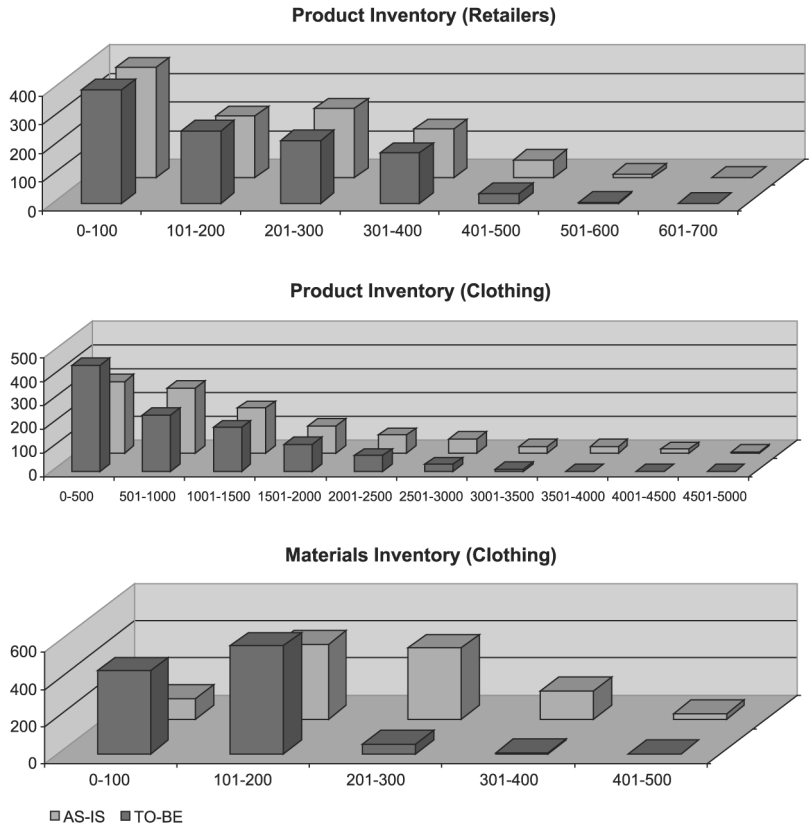
4.2.8 Production runs. The results obtained by running the AS-IS scenario were intended to be used as a basis for analysing and comparing the results of the TO-BE scenario runs. To this end, the AS-IS model needed to be modified to incorporate the expected effects of EDI adoption on the sector. Disentangling our focus of analysis from the EDI applications (the IS), and instead emphasising the business processes that EDI was called to support, proved to be useful for model modification. Since EDI is supposed to support "better demand by making it less expensive to frequently transmit demand information up the supply chain" (Bourland *et al.*, 1996), it was decided to recommend a business change scenario where companies take advantage of EDI to exchange information about expected future demand in more frequent intervals across the value chain. According to Anvari (1992), "this effect is present not only in placing the actual order, but in all data communication that takes place [via EDI]".

As a consequence, the difference between the AS-IS and TO-BE simulation models has basically to do with the business process of order plan submission. This method effectively implements the prescriptions of the theory for better demand forecasting (Srinivasan *et al.*, 1994), reduced information transmission cost (Bourland *et al.*, 1996), and reduced uncertainty in the value chain (Anvari, 1992). More frequent and better-informed demand forecasts in the case of EDI are expected to result in better adaptation of the whole value chain to the realised demand. If the theoretical predictions are valid, this improvement in demand forecasting can be hypothesised to be able to "tune" inventories along the value chain to the realised customer demand.

The above recommendations were a result of experimentation with models of new business processes and IS designs (based on using EDI). This integrated approach to BPM and IS modelling enabled us to study the alignment of business process change with IS design and investigate the feasibility of their synchronous design.

4.2.9 Output data analysis. The basic measurements taken during the course of the simulation are the daily demand faced by retail companies (customer demand) and the

daily inventory levels of each one of the companies in all stages of the value chain. Figure 3 shows the histograms of inventory level distributions in the AS-IS and TO-BE models for a number of inventory intervals. It is clear (especially for the clothing companies) that the TO-BE distributions are more skewed towards lower inventory levels. Since the same mechanisms were used for all other business processes apart from order planning and inter-company communication, it is not surprising that the output from the TO-BE scenario generally follow the same pattern as their AS-IS counterparts. Looking at the means of inventory levels in more detail (Table I) it



Note: Inventory intervals are shown on the x-axis; observed frequencies on the y-axis

Figure 3.
Inventory level distributions (AS-IS and TO-BE scenarios)

Table I.
Average levels of inventory reduction between scenarios

Category	Average inventory levels Before EDI	After EDI	Reduction (per cent)
Retailers (product inventory)	184.1	171.6	6.8
Clothing manufacturers (product inventory)	1212.0	886.5	26.9
Clothing manufacturers (materials inventory)	211.9	113.9	46.2

becomes clear that all inventory levels are significantly reduced in terms of average levels after the introduction of EDI.

5. Evaluating IS impact on business performance

An important observation during the case study was that the direct incorporation of IS impacts in BPS models was not an easy task. However, it is also an extremely important one if we want to generate the quantitative data that could drive a formal investment appraisal and the design of a proposed system. To this end, the study provided empirical support to the argument of using the business process as the mediating factor between IS adoption and business returns. In this study, the expected theoretical impacts of implementing EDI technology, were not studied in isolation. However, if the IS are accompanied by specific changes in business processes, then organisations could perhaps more easily take full advantage of the capabilities offered by the systems. What is even more important, is that simulation at this integrated level (of the business process change) seems to be easier and more intuitive than attempting to model the IS itself as an independent and standalone entity, isolated from its organisational context.

In addition to supporting the theoretical findings, the case study played an additional, perhaps even more important, role. The detailed execution of a real-life simulation model development pointed to additional issues that would have been more difficult to capture otherwise. One of these issues related to the usefulness of employing simulation as a supporting technique for business engineering. It was observed that the process of developing and using the simulation models necessitated a level of thinking that enabled us to identify business changes that were needed to leverage the IS investment. In other words, the study showed that the process of developing, validating and using simulation models for integrated design of business processes and IS can in itself be a very useful learning exercise for all participants in the study, as it generates greater awareness of both the specifications of the proposed system and the conditions of the business operations under which the system can produce the desired results, reflected in adaptable IS design.

The approach to dynamic modelling of integrated business process/IS design has been adequately illustrated by the example provided, although it is apparent that more field experiences are necessary to further substantiate these findings. Our intention was to demonstrate the feasibility of such integrated approach by using dynamic BPM. In the next section we will, amongst others, point to further research avenues that could further substantiate our findings.

6. Conclusions

The importance of ISs as an enabler of organisational change, coupled with the recursive relationships between IS and business processes, necessitate that processes and systems are considered and designed together. Although theoretically attractive, such an integrated perspective is far from easy to achieve in practice, and extant methodologies for business process change have generally failed to address this issue to a satisfactory degree. The challenge for organisational change is to bring process design and IS design together without adding to the, already high, complexity of each task alone. A potential strategy for addressing this need could involve incorporating high-level IS design and IS evaluation into business process design, and leaving the

technical details of IS implementation to be addressed in the aftermath of business engineering decisions.

We argue that it is feasible to develop simulation models that are driven by the intended business goals and IS designs, and are able to represent the business processes expected to be changed and the anticipated impacts of IS on these processes. Once implemented, such models can then be used to experiment with alternative future scenarios for business and IS change. The two sets of control variables available to the decision makers are the configuration of the proposed IS (informational changes) and the organisational arrangements regarding the structures and operations surrounding it (structural changes). Such a simulation effects a "virtual" implementation of the proposed system. By measuring the performance of the relevant business operations without the IS and with alternative scenarios regarding it, one can collect the necessary quantitative information needed to conduct further investment appraisal and IS design using established financial or other methods. Moreover, the simulation modelling process itself and the subsequent experimentation with alternative system and business configurations, can constitute additional learning processes which can improve the understanding of the implications of the system to the business domain. Such understanding can be beneficial for business managers and IS specialists alike, and therefore it can also be useful in bringing the organisational and the software engineering domains together, thus contributing to the goals of business engineering in a practical manner.

The integrated dynamic modelling of business process/IS change presented in this paper has demonstrated the feasibility of experimenting with adaptable IS structures that support dynamic changes in the business environment. Obviously, there are opportunities for further development of ideas and concepts presented in this paper. One step would be to develop easily adaptable simulation models that can serve as a quick reference to test new IS or business process alternatives. It would be also worthwhile to conduct additional empirical studies that would involve using an integrated dynamic business process/IS model on an ongoing basis that would use "live" data and reflect continuous changes in the business environment. Following changes in business processes, a model of IS would then be used to investigate the changes in IS structure needed to support changes in business processes. Should these changes in IS structure become implemented, we could move closer towards achieving a true flexible IS, which represents an important challenge for the IS community.

References

Anvari, M. (1992), "Electronic data interchange and inventories", *International Journal of Production Economics*, Vol. 26, pp. 135-43.

Arthur, L.J. (1992), *Rapid Evolutionary Development: Requirements, Prototyping, and Software Creation*, Wiley, Chichester.

Avison, D.E. and Fitzgerald, G. (1995), *Information Systems Development: Methodologies, Techniques, and Tools*, 2nd ed., McGraw-Hill, New York, NY.

Boar, B.H. (1984), *Applications Prototyping: A Requirements Definition Strategy for the 80s*, Wiley, Chichester.

Bourland, K.E., Powell, S.G. and Pyke, D.F. (1996), "Exploiting timely demand information to reduce inventories", *European Journal of Operational Research*, Vol. 92 No. 2, pp. 239-53.

Crosby, P.B. (1979), *Quality is Free*, McGraw-Hill, New York, NY.

Curtis, W., Kellner, M.I. and Over, J. (1992), "Process modelling", *Communications of the ACM*, Vol. 35 No. 9, pp. 75-90.

Davenport, T.H. (1993), *Process Innovation: Reengineering Work through Information Technology*, Harvard Business School Press, Boston, MA.

Davenport, T.H. and Short, J.E. (1990), "The new industrial engineering: information technology and business process redesign", *Sloan Management Review*, Vol. 31 No. 4, pp. 11-27.

de Vreede, G.J. and Verbraeck, A. (1996), "Animating organizational processes: insight eases change", *Journal of Simulation Practice and Theory*, Vol. 4, pp. 245-63.

Doherty, N.F. and King, M. (2001), "An investigation of the factors affecting the successful treatment of organizational issues in systems development projects", *European Journal of Information Systems*, Vol. 10 No. 3, pp. 147-60.

Doran, J. and Gilbert, N. (1994), "Simulating societies: an introduction", in Gilbert, N. and Doran, J. (Eds), *Simulating Societies: The Computer Simulation of Social Phenomena*, UCL Press, London.

Emmelhainz, M.A. (1993), *EDI: A Total Management Guide*, 2nd ed., Van Nostrand Reinhold, New York, NY.

Galliers, R.D. (1993), "Towards a flexible information architecture: integrating business strategies, information systems strategies, and business process redesign", *Journal of Information Systems*, Vol. 3 No. 3, pp. 199-213.

Giaglis, G.M. (1999), "On the integrated design and evaluation of business processes and information systems", *Communications of the AIS*, Vol. 2 No. 5.

Grover, V., Fielder, K.D. and Teng, J.T.C. (1994), "Exploring the success of information technology enabled business process reengineering", *IEEE Transactions on Engineering Management*, Vol. 41 No. 3, pp. 276-84.

Hall, H. (1994), "Information strategy and manufacturing industry: case studies in the Scottish textile industry", *International Journal of Information Management*, Vol. 14 No. 4, pp. 281-94.

Hammer, M. and Champy, J. (1993), *Reengineering the Corporation: A Manifesto for Business Revolution*, Harper Collins Publishers, New York, NY.

Harrington, H.J. (1991), *Business Process Improvement: The Breakthrough Strategy for Total Quality, Productivity and Effectiveness*, McGraw-Hill, New York, NY.

Iivari, J., Hirschheim, R. and Klein, H.K. (2000), "A dynamic framework for classifying information systems development methodologies and approaches", *Journal of Management Information Systems*, Vol. 17 No. 3, pp. 179-218.

Jelassi, T. and Figon, O. (1994), "Competing through EDI at Brun Passot: achievements in France and ambitions for the single European market", *MIS Quarterly*, Vol. 18 No. 4, pp. 337-52.

Kawalek, P. and Wood-Harper, T. (2002), "The finding of thorns: user participation in enterprise system implementation", *DataBase*, Vol. 33 No. 1, pp. 13-22.

Law, A.M. and Kelton, D.W. (1991), *Simulation Modelling and Analysis*, 2nd ed., McGraw-Hill, New York, NY.

MacArthur, P.J., Crosslin, R.L. and Warren, J.R. (1994), "A strategy for evaluating alternative information system designs for business process reengineering", *International Journal of Information Management*, Vol. 14 No. 4, pp. 237-51.

Mylonopoulos, N.A., Doukidis, G.I. and Giaglis, G.M. (1995), "Assessing the expected benefits of electronic data interchange through simulation modelling techniques", in Doukidis, G., Galliers, R., Jelassi, T., Krcmar, H. and Land, F. (Eds), *Proceedings of the Third European Conference on Information Systems*, Athens, pp. 931-43.

Paul, R.J., Giaglis, G.M. and Hlupic, V. (1999), "Integrating simulation in organisational design studies", *International Journal of Information Management*, Vol. 19 No. 3, pp. 219-36.

Purvis, R. and Sambamurthy, V. (1997), "An examination of designer and user perceptions of JAD and the traditional IS design methodology", *Information and Management*, Vol. 32 No. 3, pp. 123-35.

Reekers, N. and Smithson, S. (1994), "EDI in Germany and the UK: strategic and operational use", *European Journal of Information Systems*, Vol. 3 No. 3, pp. 169-78.

Scholz-Reiter, B. and Stickel, E. (Eds) (1996), *Business Process Modelling*, Springer-Verlag, Berlin.

Shannon, R.E. (1975), *Systems Simulation: The Art and the Science*, Prentice-Hall, Englewood Cliffs, NJ.

Sol, H.G. and Crosslin, R.L. (Eds) (1992), *Dynamic Modelling of Information Systems II*, North-Holland, Amsterdam.

Srinivasan, K., Kekre, S. and Mukhopadhyay, T. (1994), "Impact of electronic data interchange on JIT shipments", *Management Science*, Vol. 40 No. 10, pp. 1291-304.

Venkatraman, N. (1991), "IT-induced business reconfiguration", in Scott-Morton, M.S. (Ed.), *The Corporation of the 1990s: Information Technology and Organisational Transformation*, Oxford University Press, New York, NY, pp. 122-58.

Warren, J.R. (1996), "Guest editorial: simulation of information systems", *Simulation and Gaming*, Vol. 27 No. 4, pp. 438-9.

Warren, J.R. and Stott, J.W. (1992), "CASE/simulation: making performance evaluation a normal part of information systems development", in Sol, H.G. and Crosslin, R.L. (Eds), *Dynamic Modelling of Information Systems, II*, North-Holland, Amsterdam, pp. 219-50.