Process approach to supply chain integration

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Abstract

Purpose – Business renovation, the effective utilisation of information technology and the role of business process modelling and simulation, are all vital in supply chain integration projects. This paper aims to show through a combination of these methods how the performance of the supply chain can be improved with the renovation and integration of processes at various tiers in the chain and by the sharing of information between companies.

Design/methodology/approach – Simulation-based methodology for measuring the benefits of the creation and renovation of business process models combines the methodology of developing process models and its simulation with the simulation of supply and demand. A procurement process in the oil/retail petrol industry is examined in a case study.

Findings – Using the proposed methodology, different business process models can be investigated and simulated. The benefits for each company involved in the presented case are substantial and can be estimated through a simulation. Substantial benefits in costs, quality and lead times were identified, however, their distribution is not symmetric. Inter-organisational IS and applied technology were enablers for supply chain integration. However, organisational changes and new business models were prerequisites for obtaining those benefits.

Practical implications – The process approach to supply chain integration presents a mechanism that can be applied to any industry. It represents a systematic methodological business renovation approach involving cost cuts, quality improvements and lead-time improvements. The costs of supply chain integration projects were not studied. The benefits should be measured against the cost of testing the economic feasibility of such projects.

Originality/value – The effective utilisation of business process modelling and a simulation of the necessary business renovation are shown. The novel combination of business process and demand/supply simulation enables an estimation of changes in lead-times, process execution costs, quality of the process and inventory costs. Although the methodology is presented through a case study of the oil/retail petrol industry, it can also be used to estimate the benefits and monitor supply chain integration projects in other industries.

Keywords Supply chain management, Business process re-engineering, Business simulations, Modelling, Procurement

Paper type Research paper

Introduction

Today collaboration between different companies in every chain is vital for its success. Although the importance of supply chain relations is widely acknowledged, seamless co-ordination is rarely achieved in practice. The paper tackles the important question of facilitating, enabling and measuring the effect of supply chain integration supported by information technology.

The main idea is to show how the performance of a supply chain can be improved through the integration of various tiers in the chain. As the current business practice must usually be renovated to fully realise the benefits of shared information, prior realisation of the current business process and the desired future state are crucial. We show how modelling business processes can help in achieving successful business process changes. The prediction and measurement of results is vital for planning and monitoring such projects – this can be achieved with the use of a combination of the process modelling and simulations described in the last section.

This paper's main contribution is to reveal how business process modelling (specifically process maps) can be used in order to achieve improvements in sharing information and the integration of processes. Appropriate business processes are a prerequisite for the strategic utilisation of information (otherwise the sharing of information can only lead to an overload of information without much benefit for anyone involved). Business modelling techniques are of particular help in becoming fully acquainted with the processes in question and to improve them. The mere implementation of new technology without changes in a company's operation will only realise some of the possible benefits. The rest of the paper therefore mainly deals with business renovation and changes in business processes that consequently improve the flow of information.

The structure of this paper is as follows: in the next section the main concepts of supply chain management relevant to our topic are summarised. Then the importance of sharing and utilising information is examined. In the third section the maturity of supply chain processes is introduced. In the fourth section business renovation leading towards e-business is presented as a key optimiser of supply chain performance in the light of enhancing supply chain maturity.

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All the theoretical findings are illustrated in a case study of a two-tier supply chain in the oil/retail petrol industry, which encompasses a company with several petrol stations and a transporter which transports petrol from warehouses to petrol stations.

Supply chain management

The supply chain (SC) is a linked set of resources and processes that begins with the sourcing of raw materials and extends through to the delivery of end items to the final customer. While the separation of SC activities among different companies enables specialisation and economies of scale, many important issues and problems need to be resolved for successful SC operations – the main purpose of supply chain management (SCM).

According to the Global Supply Chain Forum, SCM is "the integration of key business processes from end user through original suppliers that provide products, services, and information that add value for customer and other stakeholders" (Chan and Qi, 2003). SCM is a proactive relationship between a buyer and supplier and the integration is across the whole SC, not just first-tier suppliers (Cox, 2004). Most SCM-related problems stem from either uncertainties or an inability to co-ordinate several activities and partners (Turban *et al.*, 2004).

One of the most common problems in SC is the so-called bullwhip effect. Even small fluctuations in demand or inventory levels of the final company in the chain are propagated and enlarged throughout the chain. Because each company in the chain has incomplete information about the needs of others, it has to respond with a disproportional increase in inventory levels and consequently an even larger fluctuation in its demand relative to others down the chain (Forrester, 1958, 1961). Several authors (Forrester, 1961; Holweg and Bicheno, 2002) have shown that the production peak can be significantly reduced by transmitting information directly from the customer to the manufacturer.

Another problem is that companies often tend to optimise their own performance, in so doing disregarding the benefits of the SC as a whole (local instead of global optimisation). The maximum efficiency of each chain does not, however, necessarily lead to global optimisation (Gunasekaran *et al.*, 2004). In addition, human factors should also be taken into consideration: decision-makers at various points along the SC do not usually make perfect decisions (due to the lack of information or their personal hindrances), and their decisions are also influenced by employee reward systems (McGuffog and Wadsley, 1999). Regardless of the number of difficulties and problems in SCM, the core concept of successful SCM is efficient information transfer/information sharing.

Information transfer in a supply chain

In recent years numerous studies have emphasised the importance of information sharing within the SC (e.g. Barratt, 2004; Lambert and Cooper, 2000; Lau and Lee, 2000; Stank *et al.*, 1999; Mason-Jones and Towill, 1997). While there is no doubt that information technology (IT) can greatly reduce costs, the formation of a business model and utilisation of information is also crucial. Information should be readily available to all companies in the SC and the business processes should be structured in a way so as to allow full use of this information.

Most studies in this field have taken a theoretical approach (Huang *et al.*, 2003; Byrne and Heavey, 2006) and have usually made many assumptions to solve the problem analytically (Zhao *et al.*, 2002). In addition, most of the literature is at the level of production planning and control (Huang *et al.*, 2003). This paper shows a possible approach to measuring the impact of information sharing for the whole supply chain and individual companies on a practical case study – both of which are listed in Huang *et al.* (2003) as important questions for further research. Our paper also offers some guidelines for obtaining the mentioned benefits.

It should be noted that the mere use of IT applications is insufficient to realise the benefits. It has been found that adoption of the internet by itself demonstrates no benefits in terms of reduced transaction costs or improved SC efficiency in Scottish small and medium-sized enterprises (Wagner *et al.*, 2003), and has not led to a decrease in the inventory level in Slovenian enterprises (Trkman, 2000). Further, the co-ordination of activities is also critical (Disney *et al.*, 2004). While it should not be claimed that the internet in itself reduces certain costs, the strategic utilisation of information is crucial and business process modelling and renovation can be of great help for achieving this desired co-ordination.

However, other studies have shown that information transfer brings little benefits and that most benefits from IT are due to the shorter lead-times and smaller batches (Cachon and Fisher, 2000). Similarly (Steckel *et al.*, 2004) emphasise the importance of shorter cycle times and the non-sharing of information as the main advantage. Gavirneni (2002) summarises different findings that show reductions in costs of between 0 percent and 35 percent.

This substantiates our thesis that business models have to be changed so as to facilitate the better use of transferred information – see, for example, Peppard (1999) on the importance of aligning business and information management strategies – while Tennant and Wu (2005) discuss the necessary organisational changes in order to fully reap the benefits of BPR projects. Although the exact possibilities vary from industry to industry, the main business process integration concepts presented below can be applied with minor modifications irrespective of the industry in question.

The maturity of supply chain processes

To cope with the challenges they face, organisations have to accept process-based management principles, especially those wishing to successfully manage their supply chains. The process paradigm implies a new way of looking at organisations based on the processes they perform rather than on the functional units, divisions or departments they are divided into. The perceived need for such a shift in organisational design stems from the fact that, despite the changes seen in contemporary economic and social environments, management values and principles from the industrial revolution still determine the organisational structure of many modern firms.

A process is a set of one or more linked procedures or activities that collectively realise a business objective by transforming a set of inputs into a specific set of outputs (goods or services) for another person (customer) through a combination of people, methods and tools (Zhang, 2005).

Procurement and fulfilment are the key processes in a supply chain and with the onset of the Internet they are first and foremost what have to be redesigned and reorganised (Muffatto and Payaro, 2004).

To analyse the understanding of the processes of a company and a supply chain the concept of business process orientation (BPO) can be used. The concept denotes an organisation that, in all its thinking, emphasises processes as opposed to hierarchies with a special emphasis on outcomes and customer satisfaction (McCormack and Johnson, 2001). An empirical investigation was conducted (McCormack and Johnson, 2001) to study and explore the relationship between BPO and enhanced business performance. The research results showed that BPO is critical in reducing conflict and encouraging greater connectedness within an organisation, while improving business performance.

BPO is connected with the process maturity concept (Harmon, 2003), which was designed as a reference model of the stages that organisations go through as they move from being immature to mature in their process orientation. The SCM maturity model (Lockamy and McCormack, 2004) is based on concepts developed by researchers over the past two decades and implies that a process has a lifecycle that is assessed by the extent to which the processes are explicitly defined, managed, measured and controlled. The purpose of the model is to assess at which stage the organisation and/or the supply chain is and to assist in developing a road map to help them where they want to go.

A SCM maturity model is illustrated in Figure 1. The model conceptualises how process maturity relates to the SCOR (Supply Chain Operations Reference model) framework, which was developed by the Supply Chain Council (2005), an independent non-profit organisation. It was designed for effective communication among supply chain partners and can be used to describe, measure and evaluate supply chain configurations. SCOR is based on five distinct management processes: plan, source, make, deliver and return (Bolstorff and Rosenbaum, 2003).

The model was developed upon the process maturity model (Lockamy and McCormack, 2004) and defines the following SCM maturity levels:

- *Level 1 – Ad hoc* – The supply chain and its practices are unstructured and ill-defined. Processes, activities and organisational structures are not based on horizontal processes, while process performance is unpredictable. SCM costs are high, customer satisfaction is low, functional co-operation is also low.
- *Level 2 – Defined* – Basic SCM processes are defined and documented, but the activities and organisation basically remain traditional. SCM costs remain high, customer satisfaction has improved, but is still low.
- *Level 3 – Linked* This level represents the breakthrough. Co-operation between company departments, vendors and customers is established. SCM costs begin decreasing and customer satisfaction begins to show a marked improvement.
- Level 4 – *Integrated* – The company, its vendors and suppliers co-operate on the process level. Organisational structures are based on SCM procedures, SCM performance measures and management systems are applied. Advanced SCM practices, like collaborative forecasting with other members of a supply chain, form. As a consequence, SCM costs are dramatically reduced.
- Level 5 – *Extended* – Competition is based on supply chains. Collaboration between companies is on the highest level, multi-firm SCM teams with common processes, goals and broad authority form.

In Lockamy and McCormack (2004) the relationship between the maturity of supply chain processes and overall supply chain performance is examined in a survey among organisations that were members of the Supply Chain Council. The research showed that SCM process performance is strongly related to the maturity of supply chain processes. In addition, the research indicates that direct process measures like cycle times and inventory levels are also related to the maturity of supply chain processes.

A process maturity measurement instrument can also be used to determine an organisation's current position (McCormack and Johnson, 2001) and for prescriptive purposes in process improvement efforts by indicating which maturity measurements are deficient. Some suggestions on how to raise the level of BPO and supply chain processes maturity are given in the next section.

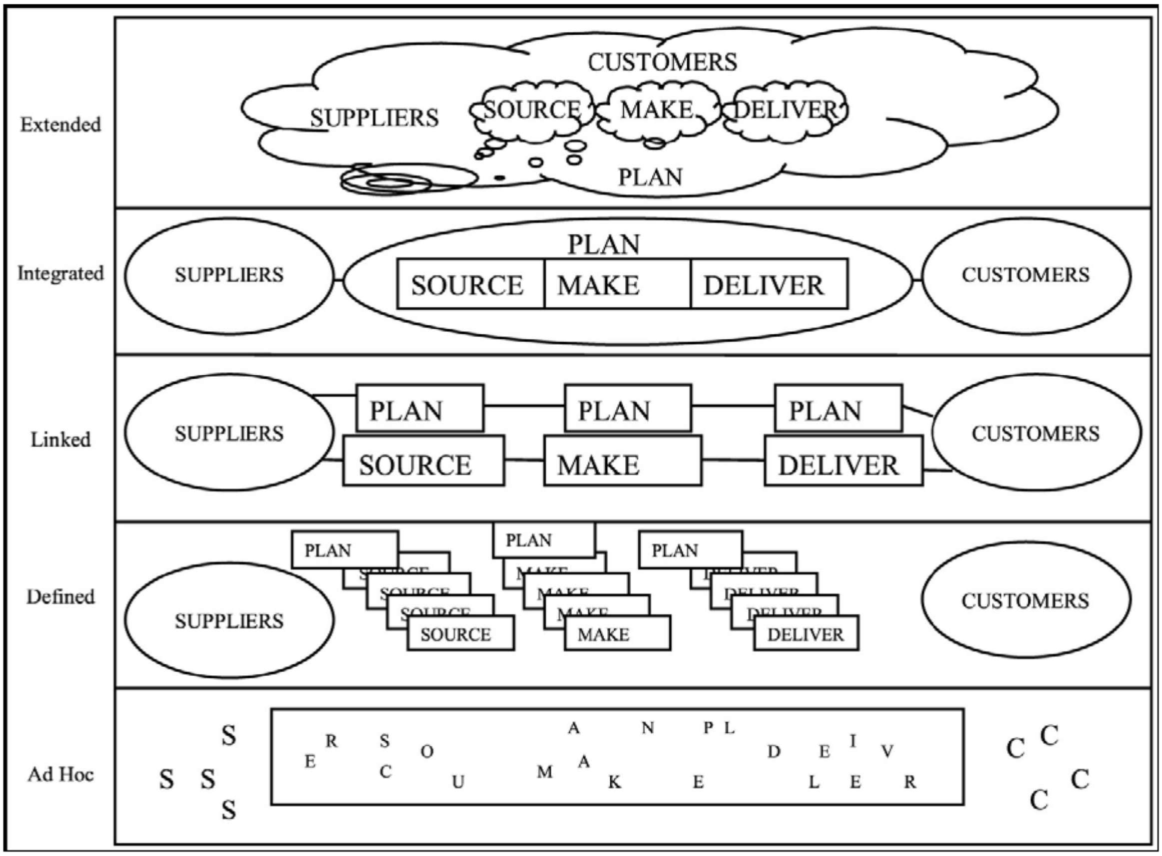
Enhancing supply chain process maturity with business renovation leading towards e-business

Business renovation (BR) or business process renovation and informatisation efforts integrate the radically strategic method of business process re-engineering (BPR) and the more progressive methods of continuous process improvement (CPI) with appropriate IT infrastructure strategies. Process renovation is a re-engineering strategy that critically examines current business policies, practices and procedures, rethinks them and then redesigns the mission-critical products, processes and services (Prasad, 1999). CPI refers to minor and specific changes that one makes in an existing business process (Harmon, 2003). It relies on building a fundamental understanding of customers' requirements, process capability, and the root cause of any gaps between them. This is a systematic approach as opposed to the classic short-cut of problem detection and subsequent solving (Tenner and DeToro, 1997). Six sigma and total quality management (TQM) are examples of approaches to CPI.

BR argues for a balanced approach in which we attempt to manage realistic changes rather than always seeking radical change. According to Jacobson (1995), we view business renovation as an umbrella concept for strategic IS planning, and both BPR and business improvement. For a thorough and effective renovation, organisations should combine radical shifts (BPR) with those that permanently increase business efficiency and effectiveness (CPI).

As the internet becomes a very important component of companies' information systems, it is playing an ever more significant role. The internet enables companies of all sizes to develop new online business models, which means improving and altering the ways in which companies operate and interact with their business partners, customers and suppliers. Companies are now pursuing more intensive and interactive relationships with their suppliers, collaborating in new product development, integrating key business process and cross-functional information sharing on a range of issues (McIvor *et al.*, 1997). The internet enables the complete integration of inter-organisational processes in BR projects and extends the strengths of BR to the new strategic options (e.g. electronic

Figure 1 Supply chain processes maturity model



Source: Lockamy and McCormack (2004)

distribution), new possibilities for processes (e.g. order entry, distribution, online payment) as well as technical issues (e.g. the integration of enterprise resource planning systems (ERP) with electronic commerce (e-commerce), SCM, customer relationship management (CRM) etc.).

E-business is the execution by electronic means of interactive, inter-organisational processes (Cunningham and Froschl, 1999). E-business represents a shift in business doctrine that is changing the traditional organisational models, business processes, relationships and operational models that have been dominant for the past 20 years. The new doctrine of e-business requires an enterprise to integrate and synchronise the strategic vision and tactical delivery of products to its customers with the IT and service infrastructure needed to meet that vision and process execution (Phipps, 2000). In the next few years, successful enterprises will restructure their organisation, process and technology infrastructure to ensure successful e-business execution.

However, it should be noted that IT alone is no panacea for all SC problems. Further, the most often quoted problems of online purchasing are not related to technology but to logistical and SC problems (Hoek, 2001). This is even more relevant to traditional companies that are usually even less prepared for the new e-commerce-related challenges.

The efficiency of SCs can generally be improved by, for example, reducing the number of manufacturing stages, reducing lead-times, working interactively rather than independently between stages, and speeding up the information flow (Persson and Olhager, 2002). It has been shown that electronic data interchange (EDI) can reduce swings in inventory and safety stock levels. The simulation results show that (among other improvements) the standard deviation of stock levels is considerably reduced (Owens and Levary, 2002).

Business process modelling

The main purpose of developing and analysing business process models is to find revenue and value generators within a reversible value chain, or a business model's value network. There have been a number of attempts to formally describe and classify a business process model. Venkatraman and Henderson (1998) defined a business process model as a co-ordinated plan to design strategy along three vectors: customer interaction, asset configuration and knowledge leverage (Venkatraman, 2000).

A business process model is an abstraction of a business that shows how business components are related to each other and how they operate. Its ultimate purpose is to provide a clear picture of the enterprise's current state and to determine its vision for the future. There are several reasons for producing business process models (Eriksson and Penker, 2000):

- *A business process model helps us understand the business* – One of the primary goals of business process modelling is to increase our understanding of the business and to facilitate communication about the business.
- *A business process model is a basis for creating suitable information systems* – Descriptions of the business are very useful in identifying the information systems needed to support the business. Business process models also act as a basis for engineering requirements when a particular information system is being designed.
- *A business process model is a basis for improving the current business structure and operation* – As it shows a clear picture of the business current state a business process model can be used to identify the changes required to improve the business.
- *A business process model provides a polygon for experiments* – A business process model can be used to experiment with new business concepts and to study the implications of changes for the business structure or operation.
- *A business process model acts as a basis for identifying outsourcing opportunities* – By using a business process model the core parts of a business system can be identified. Other parts considered less important can be delegated to external suppliers.

Modelling a complex business requires the application of multiple views. Each view is a simplified description (an abstraction) of a business from a particular perspective or vantage point, covering particular concerns and omitting entities not relevant to this perspective. To describe a specific business view, several diagrams are usually used and complemented with textual descriptions. For the efficient and effective integration of business processes in the supply chain first of all existing processes have to be fully understood and documented (AS-IS models), i.e. they should be at least at the second level of the previously described supply chain processes maturity level model (Lockamy and McCormack, 2004). Business process modelling and the evaluation of different alternative scenarios (TO-BE models) for improvement by simulation are usually the driving factors of the business renovation process (Bosilj-Vuksic *et al.*, 2002). Techniques that enable the modelling of business processes, the evaluation of their performance, experimenting with alternative configurations and process layouts, and comparisons between diverse proposals for change are highly suitable for organisational design (Giaglis *et al.*, 1999).

In the next section a detailed case study of a petrol company is presented.

Case study

A case study has been used as a research method to underline the theoretical findings set out in previous sections, i.e. to show how the performance of the supply chain can be improved with the renovation of inter-company processes. In addition, the purpose of the case study is to show how the benefits of supply chain process renovation and integration can be assessed using the proposed combination of business process modelling and simulation.

The case study is used extensively as a research strategy in practice-oriented fields such as management (Yin, 2003). The research presented is only partly of an exploratory nature in researching the possibility of assessing supply chain process renovation and integration benefits. In the other part, the investigation of the renovation of the impact of inter-company processes on supply chain performance is also of an explanatory nature. Still, the case study is an appropriate research method as the research questions are of the "how" type in their substance. This type of research question is likely to lead to the use of case studies, histories and experiments as the preferred research strategies (Yin, 2003).

The case study as a research strategy has a distinct advantage in situations when "how" or "why" questions are being asked about a contemporary set of events over which the investigator has little or no control (Yin, 2003), which is also the case in the research presented here. In addition, there are many more variables of interest required by simulation modelling than there are available cases for analysis, which is the main reason the survey as a research strategy was inappropriate and again led to the use of the case study.

The case study presented in this paper deals with the fulfilment/procurement process in an SC that contains a petrol company (with multiple petrol stations at different locations) and a supplier who transports the petrol to the petrol stations from a few large warehouses.

The business process modelling and renovation project was initiated by the petrol company in order to reduce operating costs, shorten lead times and improve stock management. The project started with the formation of a project group consisting of members of the petrol company, the transport company, and consultants. The first step of the project was a workshop for the project group in which the members were acquainted with the project goals and methodology. After the workshop, key business process groups were identified by discussion and brainstorming. One of the most crucial processes was the procurement process.

The processes were modelled by interviewing people from the companies that perform the activities. This phase of the project was very difficult and lasted for almost six months; the models had to be changed several times in order to bring them as close to the real business operations as possible. Since the models reflect business operations, key personnel from both companies were involved and the final version of the AS-IS model was validated by the relevant managers of both companies. Then, the consultants analysed the key business processes on the basis of their models. The results of the analyses became the starting point for the renovation of the business processes.

In line with the aim of the paper only a fragment, namely the procurement process, will be shown in the next section. A broader description of the case study can be found in Groznik and Mujkic (2005), whereas here the most relevant aspects of the case are used to explain the theoretical concepts mentioned above.

Case studies typically combine data collection methods such as interviews, questionnaires and observations (Eisenhardt, 1989). The evidence may be qualitative, quantitative, or both. Special care has been taken in supporting the case study with data. Data regarding business processes (e.g. processes, sub-processes, activities, costs, time leads) was acquired during business process modelling and provided by the companies involved in the supply chain on an interview basis. Since business process models are an abstraction of the supply chain operations, it was vital for the case study to ensure that the business process simulations fitted with realistic supply chain operations. The data quality was cross-checked and fine tuned when comparing the results of business process simulations with real life data. Apart from business process data, we also used industry-specific data (e.g. oil prices, tank volumes) which is available from the literature (White, 2005; Wu, 2006).

Obviously this is a specific case study with a standardised product and only one supplier, so the results cannot be generalised to other industries without caution. From the supply chain point of view, the oil industry is a specific business. The oil industry supply chain is divided into upstream and downstream supply chains. The upstream supply chain includes research, drilling, offshore activities and transportation to the refinery. The downstream supply chain involves distribution and retail. The case presented here deals with the downstream supply chain. Both the theoretical findings and methodological approach for measuring integration benefits can be applied equally, regardless of the number of companies in the chain. The approach enables measurement of the total benefits and the benefits of each company in the chain.

AS-IS model development

The main goals are similar to the usual SC goals: to offer good service to the final customer, while keeping costs and lead-times low. As both the prices and quality of petrol in Europe are regulated, the main quality indicator is the number of stock-outs. The main cost drivers are therefore the number of stock-outs, the stock level at the petrol station and the process execution costs (work, transport, etc.). The lead-time is defined as the time between the start (measurement of the stock level) and the end (either the arrival of petrol or the decision not to place an order) of the process.

The description of the current process is as follows: the stock level is measured manually once a day. The results are faxed to the purchasing department, which collects information from all petrol stations. It predicts future demand, while taking seasonal and cyclical movements into account. An additional consultation with a petrol station manager is possible, if needed. The needs of several petrol stations are merged into one order. Tacit employee knowledge is used to make and optimise orders and transport routes.

The analytical department controls possible changes in demand and supply patterns and transport routes. If necessary, it can adjust or cancel orders. After that, the order is sent to the transport company – this is also the first information given to the transport company about the needs. The order has to be fulfilled with the available fleet, but cannot be modified. Financial compensation is paid to the transporter for its services based on the number of miles driven, petrol delivered and the punctuality of deliveries.

While the description focuses on one typical petrol station, the inputs from other stations are also taken into account at various points in the model. Most importantly, the capacity of each truck is considerably higher than the needs of one station, so orders from different stations are usually merged into one.

Based on the process described above, an AS-IS model was developed. Process maps were used for visualisation of the model. Process maps are the standard method for modelling and analysing during business renovation. One of their main advantages is that employees can be taught quickly how to develop and validate these models (Chen, 1999). They enable analyses of the costs and time needed for the process (Indihar Stemberger *et al.*, 2004). The Igrafx Process 2003 with a graphical user interface was used – such an interface enables an easy understanding of everything involved in the project (Bosilj-Vuksic *et al.*, 2002) – this is especially vital in a SC context as employees from different companies must understand the developed models.

Based on the description above the AS-IS model was developed as shown in Figure 2. The developed model was validated by employees in both companies. The two businesses, shown in Figure 2, are the petrol company and the transport company.

The developed business model helps us to understand the current problems and also makes them more visible to all decision-makers in both companies. As described above, they were also involved in identifying the following problems.

The main problems identified on the tactical level are:
- the stock level cannot be measured accurately with a measuring stick, since the tank always contains some water (the exact quantity of water is unknown);
- the communication between various departments and companies is costly (using telephones, fax machines etc.); and
- the transport company's trucks are not fully utilised.

However, even bigger problems are found on a more strategic level, such as:
- the flow of information in the process is slow and costly – the process is also not being executed efficiently;
- full information is not available when making a decision (e.g. the purchasing department does not have much information about the truck fleet);
- the prediction of future demands is approximate, based on human tacit knowledge;
- human limitations prevent the decision-maker from using all available information (e.g. stock levels at all petrol stations);
- each member in the chain is trying to attain its local optimum instead of the global chain's optimisation; and
- consequently, both stock levels and transport costs are higher than necessary.

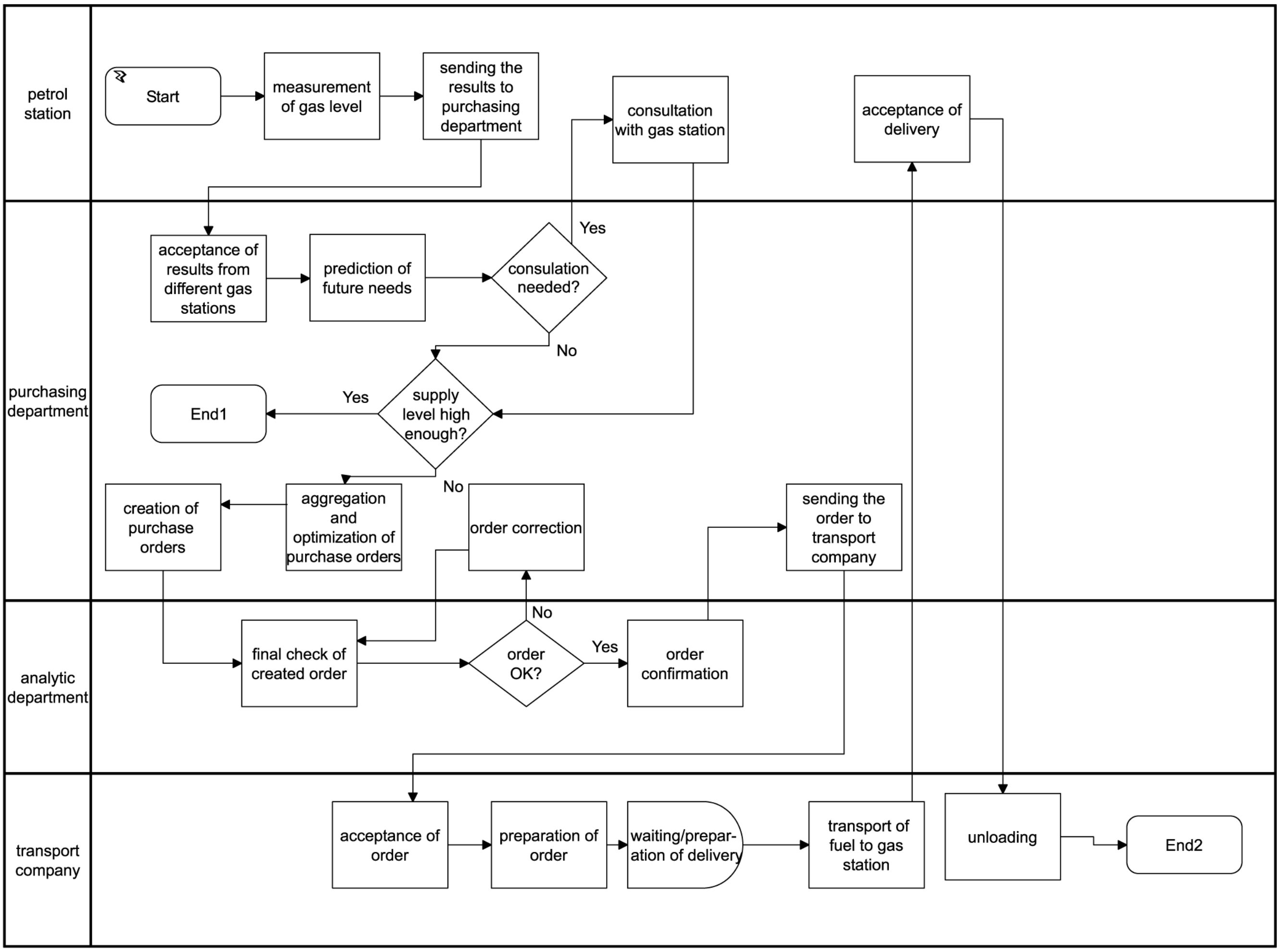
Business process modelling plays the role of a facilitator of changes. It helps to identify some of the problems mentioned above. In connection with simulations it also helps to measure the benefits of the changes. As the current state of processes is now clear to all those involved (employees in both companies and various departments), it is easier for them to suggest possible improvements to the model and consequently convince them to accept necessary changes. Human resistance is usually one of the main hindrances in the implementation of changes (Bay *et al.*, 2004; Burgess, 1998; Kidd *et al.*, 2003).

Business renovation

Based on the mentioned problems, several improvements are proposed. The main change is that the processes at both companies are now integrated and the supplier takes responsibility for the whole procurement process. The renewed business model is shown in Figure 3.

Although all phases are supported by IT, deep structural changes were needed to fully realise the potential benefits. Some of the proposed changes can be described with the popular buzz-word "vendor-managed inventory" (VMI); others, like material requirements, planning, data mining,

Figure 2 AS-IS model of the process



operations research, etc., can be gathered together under the umbrella term SCM. It is, however, the interconnection of those changes that brings about the desired benefits.

The chief idea is that the transport company takes a strategic role in providing a sufficient inventory level to fulfil the demand of the end customer. It takes all important decisions regarding orders in order to realise this goal.

The main changes that are proposed are:

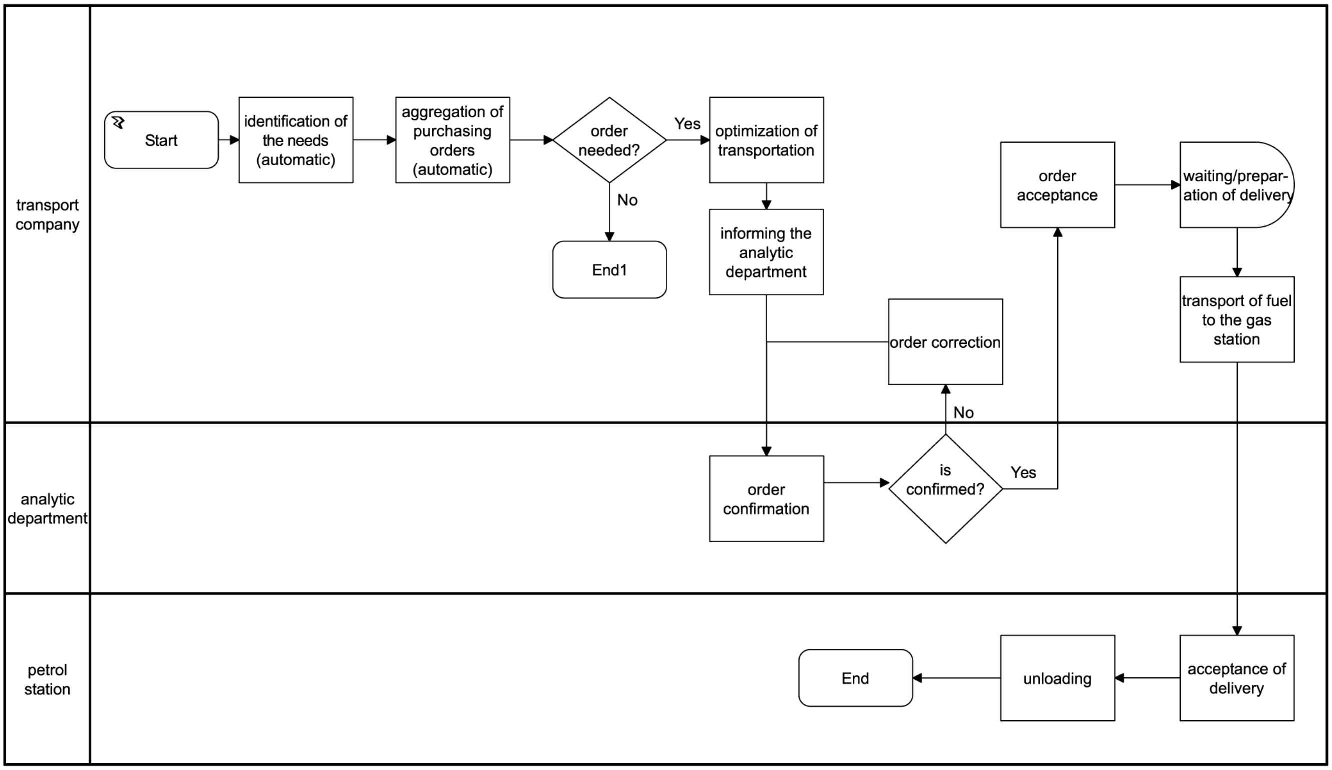
- the measurement of petrol is now fully automatic – stock-level information is exact since the sensors in the installed measurement system measure the components in the tank in real time;
- the stock levels from all petrol stations are instantly available to the transport company via inter-organisational IS;
- future demand is predicted using the model based on neural networks;
- the system at the transport company automatically identifies the current levels of stock, predicted future needs, and suggests possible orders and delivery distribution among different petrol stations;
- the final decision is made daily by an employee in the transport company and is approved by the petrol company;
- operations research methods (e.g. the vehicle routing problem) are used to optimise transportation paths and times (see Gayialis and Tatsiopoulos, 2004 for a detailed description of such a system); and
- in the long-term the locations of the warehouses can also be optimised.

Further advantages not directly visible from the figures include:

- due to the use of optimisation methods with full information being available the transport is more efficient;
- similarly, the activity "preparation of delivery" is shortened and mostly automated; and
- the predictions of future demand are considerably improved, from a decision based on tacit knowledge to the developed neural networks: therefore, the real demand deviates less from the estimate than before.

The role of IT in all these suggestions is crucial. An automatic system for the measurement and communication of current levels of stocks at all stations, neural networks, computer-assisted operation research methods, etc., enable the changes. While it becomes possible to develop an information system to support the AS-IS model, it would be much more

Figure 3 TO-BE model of the process



beneficial to introduce process renovation and related organisational changes.

Based on the maturity model for the processes (Lockamy and McCormack, 2004) the AS-IS model at both companies can be classified at the second level of the fifth-level scale because all processes are documented. The TO-BE model is on the fourth level (integrated) because all co-operation between both companies is taken to the process level. Both organisational structures and jobs are based on processes. The transformation to the fifth level (extended) is not immediately possible as deep mutual trust is a prerequisite, although investment in site-specific assets can boost mutual trust between parties.

Petrol supply chain and the transfer of information

Special attention in renovation efforts is paid to changes in the transfer of information. IT would enable an efficient and cheap transfer even in the AS-IS model as the use of e-mail or an extranet can facilitate instant access to all available information to both the petrol and transport companies. However, put simply that would realise little of the possible benefits. As shown in Cachon and Fisher (2000), most of the necessary information is already contained in sent and received orders.

IT certainly plays an important role in both acquiring information (exact instantaneous data about the level of petrol would otherwise be impossible) and utilising it (the usage of neural networks for predicting future demand patterns). Certain advantages could be realised from the exact information about stock levels (with the automated system). However, the main advantages lie in the possible organisational changes outlined in the case study.

The main effects of the enhanced flow of information are two-fold:

1 An earlier start and better flow of the business process: as the needs are identified at the supplier the fulfilment process can start immediately, without any unnecessary delays.
2 The main decision about transport is made with full information about both the needs of petrol stations, the prediction of future demands and the available truck fleet and their associated costs. Previously, the decision about order quantities was made by the purchasing department (with partial informal help from the petrol station and analytical department), while the decision about transport was taken by the transport company based on the given orders.

Consequently, previously only local optimisation of each company in the chain was possible. The transferred information in the AS-IS model would only help make the search for local optimisation slightly better. The TO-BE model, however, enables both improvements at a single company (local optima) and at the global SC level. The transfer of information is therefore only sensible if the business process is structured in such a way that it can also be utilised in decision-making.

Measuring the effects

The effect of the changes can be estimated with simulations. The results of the simulations enable the measuring of the effects of possible experiments in business process models (Eriksson and Penker, 2000). In our example we used a combination of a simulation of business processes (the methodology, advantages and some problems of this approach are presented in detail in Bosilj-Vuksic *et al.*, 2002) and simulations of supply and demand, which partly uses the results of the first simulation. Both simulations were run for both the AS-IS and TO-BE models in order to estimate the effect of the transformation of the business model and integration of processes.

With the first simulation we estimated changes in process execution costs, lead-times and employee workloads. The methodology used (Bosilj-Vuksic *et al.*, 2002) does not enable the direct measurement of the quality of the process and/or its outputs. Therefore, a second simulation was used to estimate changes in the quality, level and costs of stock.

Both simulations are especially important as they enable us to estimate the consequences of possible experiments. The possible benefits of such changes have to be carefully weighed up against the costs needed to make those changes to find out the business feasibility of such changes (as shown in Groznik and Mujkic, 2005).

First a three-month simulation of both the AS-IS and TO-BE models was run. In the AS-IS model a new transaction is generated daily (the level of petrol is checked once a day); in the TO-BE model it is generated on an hourly basis (the level of stock is checked automatically every hour). In the AS-IS model the following employees take part:

- analyst;
- purchasing worker;
- petrol station manager;
- petrol station worker;
- transport worker; and
- driver.

Their hourly wages are considered in the model. In addition, transport vehicle (road tanker) costs are included in the simulations of the model. In the TO-BE model the petrol station manager and purchasing worker are no longer needed.

The simulations enable the measuring of both the effects on the SC as a whole and at each company and department involved. The cost of each activity or sub-process can also be estimated. The convincing results are summarised in Table I. The label "Yes" refers to those transactions that led to the order and delivery of petrol, while the label "No" means a transaction when an order was not made since the petrol level was sufficient.

The average process costs are reduced by almost 70 percent, while the average lead-time is cut by 62 percent. From this it is clear that this renovation project is justifiable from the cost and time perspectives, while the quality changes cannot be directly measured by these business process simulations.

Another interesting observation is that even every NO transaction in the AS-IS model costs £44 for every petrol station each time (that is on a daily basis). These costs are due to the time and costs needed for communication, consultation and decision about orders, even when an order is not placed. They are almost completely removed in the TO-BE model due to changes in the process and automation of those activities.

The simulations also enable an estimation of the benefits for each department or organisation. While we seek a global instead of a local optimum, it should be noted that an individual company is unlikely to become involved in such a renovation project unless it can expect benefits for itself. The results in Table II show that both companies can realise important savings – the results can be used to convince them of the justifiability of the project. The main savings are realised by the petrol company, while the transporter also makes considerable savings that are, however, smaller because it has to take responsibility for some activities previously performed by the petrol company.

The results of the simulations of the AS-IS model are approximately in accordance with the current state of the company, which further validates the model.

Since using such a simulation of business processes does not directly enable the measurement of changes in quality, some additional simulations were run. The results of the business process simulation were used as an input for a simulation of the supply and demand of petrol. A three-month simulation of level of stock at a petrol station that is open 24 hours per day was run.

Inputs into the simulation include cycle times (average and standard deviations were the result of the simulation of business processes), demand prediction for various times of the day (using the old method and the new neural networks-based method) etc. Each order consists of 30,000 litres of petrol. The company places a new order when the perceived level of petrol reaches a certain level – this is the so-called reorder point. In the TO-BE model the perceived level of petrol is the same as the actual level, while in the AS-IS model a 5 percent variation is possible due to an inaccurate measurement method. The purpose of the simulation is to estimate the optimal reorder point and the level of costs for this point for each simulation. The cycle time for both models is a result of a first simulation. Other inputs (e.g. costs for holding a unit of inventory, costs of stock-outs, mistakes in the measurement of petrol in the AS-IS model) were obtained during the project.

Table II Total costs per department (three months)

Department	AS-IS (£)	TO-BE (£)	Index TO-BE (AS IS = 100)
Analytic department	27.93	39.30	141
Petrol station	469.94	90.95	19
Purchasing department	4,380.91	0.00	0
Petrol company total	4,878.79	130.25	3
Transport company	10,687.46	3,747.70	35

Table I Comparison of simulation results for the AS-IS and TO-BE models

Transaction	Number	Average lead time (in hours)	Average work (in hours)	Average wait (in hours)	Average costs (£)
Yes (AS-IS)	22	28.53	14.06	13.61	572.43
No (AS-IS)	67	5.39	4.6	0.00	44.36
Yes (TO-BE)	22	10.82	5.87	4.94	173.82
No (TO-BE)	1,058	< 0.01	< 0.01	0.00	0.05

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The simulation was run with Goldsim Pro 9.00. Simulations with different reorder points and safety stocks were run with 30 realisations of each simulation. Three different situations were studied:

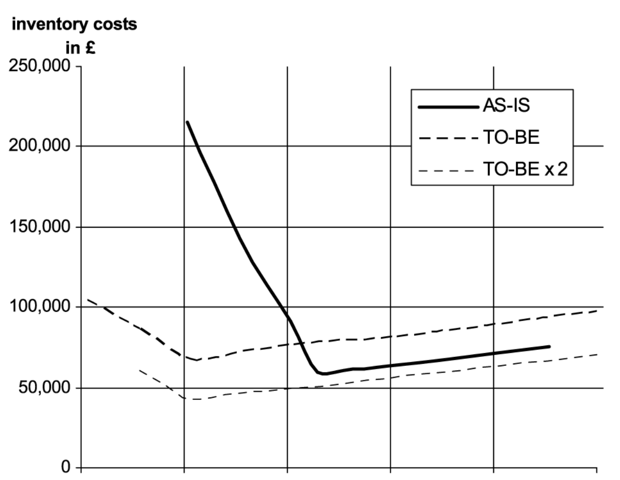
1. the current situation in the AS-IS model;
2. the TO-BE model with the same number of orders; and
3. the TO-BE model with twice the number of current orders.

These simulations can be used to show the estimate of total inventory-related costs and the number of stock-outs in correlation with the level of stock. As stated, the main aspect of quality is the number of stock-outs. Further, inventory-related costs are also estimated as the sum of holding inventory and the costs of stock-outs. In Figure 4 the relation between the reorder point and inventory costs is shown. Inventory costs are the sum of inventory holding costs and the costs and loss of profit for each stock-out. The situation in the AS-IS model is shown with a full line, the situation in the TO-BE model with a dashed line, and in the TO-BE model with more frequent orders with a dotted line.

The recommended reorder point is visible for all three situations. The reorder point is much lower in both renewed models. This is mainly due to the considerably reduced lead time between the placement of an order and delivery of the petrol. However, it is obvious that while the cost-curve has shifted to the left in the TO-BE model, the inventory costs at the optimal reorder-point have not decreased. This implies that, put simply, a reduction in process lead-times and costs does not lead to a change in optimal inventory costs. However, since the costs of one order are reduced by 70 percent it is possible to double the number of orders and still reduce the previous total order costs by 40 percent. Then, the increase in order frequency means a considerable reduction of inventory costs.

The results of both simulations support the contention that, at least in our case, the transfer and utilisation of information drastically reduces the costs, lead-times and employees' workload, while smaller and more frequent orders have the strongest influence on inventory levels and costs. Yet it should not be forgotten that the process changes and reduction of process costs enable more frequent orders in the first place.

Figure 4 Total inventory costs in relation to reorder point



Obviously the proposed TO-BE model is not the ultimate solution to all supply-chain related problems. Continuous monitoring and improving of the business model is necessary. The visibility of the process in the whole chain and the ability to estimate further changes with a developed simulation framework will serve as an important enabler of a continuous process improvement.

Potential implementation problems

While the main advantages of the proposed changes are clear, certain problems might become an issue. Apart from technological issues, the following issues were identified:

- A new way of thinking since employees will have to seek solutions on overall SC-levels instead of local optima. According to Burke and Peppard (1995), human-related issues are far from ignorable.
- The different organisational cultures and leadership styles will have to be aligned to suit the SC. Companies forming the SC have to transform their organisational cultures and leadership styles in order to support the SC benefits.
- A loss of control since, with the changes, the petrol company effectively loses control over the process. It does retain some control as its employee has to formally approve the order – this would not be necessary from a process viewpoint but remains in the model in order to slightly reduce the loss of control by the petrol company. Although certain aspects can be legally arranged, a high level of trust between companies is a prerequisite for making the SC-specific investments as required in our case (see, for example, Handfield and Bechtel, 2002 for both a literature review and further research on the impact of mutual trust on cycle times and SC effectiveness as a whole).
- The sharing of information can namely be problematic as the companies in the SC may not be prepared to share their production data, lead-times, especially when these companies are independent of each other (Terzi and Cavalieri, 2004). Indeed, the lack of trust between business partners is one of the main hindrances to collaboration in the SC context (Ireland and Bruce, 2000; Barratt, 2004).
- Asymmetric distribution of costs and benefits since substantial investments are needed from both sides, but the transporter realises fewer benefits while taking on new responsibilities and a more strategic role in the process. Therefore, the financial compensation plan for its services also has to be changed from the previous system based on the number and punctuality of deliveries to a system based on the quality of services for the final customer and the average inventory costs for the petrol company.

Conclusion

In the paper we analysed the main aspects needed for the successful renovation, integration and operation of SCs. The core idea is that the successful implementation of SC integration projects is not as much a technological problem and that a thorough study of the current and desired states of business processes in all companies involved is required.

The case study showed a two-phase approach to estimating the different benefits of business process renovation with the use of simulations. The transfer of information brings important advantages to both companies involved in process costs and lead-times, while the resulting possibility of smaller and more frequent orders means reduced inventory costs.

Inter-organisational IS and applied technology were enablers for supply chain integration. However, the organisational changes that turned the petrol transporter into a strategic partner were the key to the process improvements that led the process to the fourth level of process maturity. In order to achieve the fifth level of supply chain maturity, further efforts are required. More improvements could be achieved when the redesigned process is continuously managed and improved. Therefore, business process renovation and integration should not be considered as a one-time project, but as a permanent process performance measurement, analysis and a continuous improvement of supply chain processes. The developed simulation framework can be used as a guideline for performing all those activities.

Since this might considerably change the power distribution between the participating organisations, an additional level of trust and collaboration between the petrol and transportation companies has to be ensured.

The proposed approach is applicable to a wide range of supply chains in different industries, regardless of the number of organisations participating. The method of business process modelling combined with the simulations presented in the case study can be used for multi-tier supply chains with no major changes. As the proposed method of process integration based on the redistribution of responsibilities and power requires a long-term partnership between the companies involved, the approach is mostly applicable to the lean type of supply chains.

The chief benefit of the presented approach is its extension of the widely used business process simulation modelling methods for assessing the expected results of the proposed changes in supply chain processes. The method has been extended with additional simulations to estimate changes in the quality level and costs of stock. It allows a deeper understanding of the consequences of introduced new technologies and intra-organisational IS as enablers of process and organisational changes. As a result, the return on investments can be estimated more easily.

The validity of the model in the case study was tested by comparing the AS-IS model to the actual state in the organisations. The results of the AS-IS model simulation were validated as well. The case study presented shows the applicability of the proposed approach; however, further case studies have to be done in the future to prove the validity of the concept itself.

The study also has some limitations. In the case study the costs have not been estimated because this was not the focus of the research. Another problem in implementing the approach might be the difficulty of gathering the data required for process modelling and a simulation-based analysis.

Additional future work could involve an incorporation of the presented approach into the business process management concept. In this way it could be used for a real-time evaluation of process execution results and consequently to enhance CPI practices. The possibility to extend business process simulations with data on stock levels and costs should also be studied.

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