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Measurement of Supply Chain Integration Benefits

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Abstract

The paper deals with business renovation, effective utilization of information technology and the role of business process modeling in supply chain integration projects. The main idea is to show how the performance of the supply chain can be improved with the integration of various tiers in the chain. Integration is prerequisite for effective sharing and utilization of information between different companies in the chain. Simulation-based methodology for measuring the benefits combines the simulation of business processes with the simulation of supply and demand. The theoretical findings are illustrated with the case study of procurement process in a petrol company. Old and renewed business process models are shown. The changes in lead-times, process execution costs, quality of the process and inventory costs are estimated.

Keywords: supply chain management, business process renovation, simulations, information transfer

Introduction

Today collaboration between different companies in the chain is vital for the success of each chain. Although the importance of supply chain relations is widely acknowledged, seamless coordination is rarely achieved in practice. The paper tackles the difficult question of facilitating, enabling and measuring the effect of supply chain integration supported by information technology (IT).

The main idea is to show how the performance of the supply chain can be improved with the integration of various tiers in the chain. As the renovation of the current business practice is usually necessary to fully realise the benefits of shared information, the prior realisation of the current business process and the desired future state is vital. We show how the modelling of business processes can help in achieving successful business process changes. The prediction and measurement of results is crucial for planning and monitoring such projects– this can be achieved with the use of the 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 develop such business process models that will lead to improvements in sharing the 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 benefits for anyone involved). Business modelling techniques are of great 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 realise

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only some of all 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 SCM relevant to our topic are summarised. Then the importance of sharing and utilising information is examined. In the fourth section business renovation towards e-business is presented as a key optimiser of supply chain performance.

All the theoretical findings are illustrated with a case study of a two-tier supply chain in the petrol industry (a company with several petrol stations and a transporter which transports fuel 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 the delivery of end items to the final customer (Bridgefeld Group ERP/Supply Chain Glossary, 2004). 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 a successful SC operation – 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 stakeholder' (Chan & Qi, 2003). We can only talk about SCM if there 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 either from uncertainties or an inability to co-ordinate several activities and partners (Turban, McLean, & Wetherbe, 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 & Bicheno, 2002) have shown that the production peak can be significantly reduced by transmitting the information directly from the customer to the manufacturer.

Another problem is that the 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 however does not, however, necessarily lead to global optimisation (Gunasekaran, Patel, & McGaughey, 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), their decisions are also influenced by employee reward systems. (McGuffog & 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. Barrat, 2004, Lambert, & Cooper, 2000; Lau, & Lee, 2000; Mason-Jones, & Towill, 1997; Stank, Crum, & Arango, 1999). Ferbar (2004) derives a mathematical model that shows how different changes in ordering costs as a result of using e-business can affect the optimal ordering intervals and quantity, average stock level and consequently total inventory-related costs.

While there is no doubt about the fact that IT can greatly reduce the costs, business model formation and utilization of information is crucial. Information should be readily available to all companies in the SC and the business processes should be structured in a way to allow full use of this information. Additionally; ICT has an important influence on coordination structure between companies. The use of ICT may have a positive effect on coordination, can lower coordination costs and enables more effective and more efficient coordination processes, more coordination processes, and new coordination structures (Hengst & Sol, 2001)

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, Fillis, & Johnasson, 2003), and has not led to a decrease in the inventory level in Slovenian enterprises (Trkman, 2000). Further, the co-oordination of activities is also crucial (Disney, Naim & Potter, 2004). The Internet reduces much of the costs of information sharing, but it does not solve information receivers' reading and interpretation limitations. A possible approach to these problems as information market problems with solutions consisting of information market service process models is shown in (Wijnhoven, 2001).

Strategic utilization of the information is of the utmost importance and business process modeling and renovation can be of great help in achieving this desired coordination.

However, other studies have showed that information transfer brings little benefits and that most of the benefits from IT are due to shorter lead times and smaller batches (Cachon, & Fisher, 2000). Similarly, Steckel, Gupta, and Banerji (2004) emphasize the importance of shorter cycle times and not sharing of information as the main advantage. Gavirneri (2002) summarizes different findings that show reductions of costs between 0% and 35%.

This substantiates our thesis that business models have to be changed so as to facilitate the better use of transferred information. 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 paper presents a novel combination of methodological approaches for measurement of SC integration benefits and thus expands the previously published paper (Trkman, Indihar-Stemberger & Jaklic, 2005)

Business Renovation into E-Business

Business Renovation (BR) or business process renovation and informatization efforts integrate radical strategic method of Business Process Reengineering (BPR) and more progressive methods of Continuous Process Improvement (CPI) with adequate IT infrastructure strategies. Process renovation is a re-engineering strategy that critically examines current business policies, practices and procedures, rethinks them through and then redesigns the mission-critical products, processes, and services (Prasad, 1999).

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, organizations should combine radical shift (BPR) with those that permanently increase business efficiency and effectiveness (CPI).

As the Internet becomes very important component of companies' information systems, it plays a 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 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, Humphreys, McAleer, 1997). The Internet enables complete integration of inter-organizational processes in BR projects and extends the strengths of BR to the new strategic options (e.g. electronic distribution), the new possibilities for processes (e.g. order entry, distribution, on-line payment) as well as the technical issues (e.g. integration of Enterprise Resource Planning systems (ERP) with Electronic Commerce (E-commerce), SCM, Customer Relationship Management (CRM) etc.). Figure 1 shows how those extended business processes relate to the technical issues or so called electronic business /e-business) applications.

E-business is the execution by electronic means of interactive, inter-organizational processes (Cunningham, & Froschl, 1999). E-business represents a shift in business doctrine that is changing traditional organizational 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 synchronize 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 organization, process and technology infrastructure for successful e-business execution.

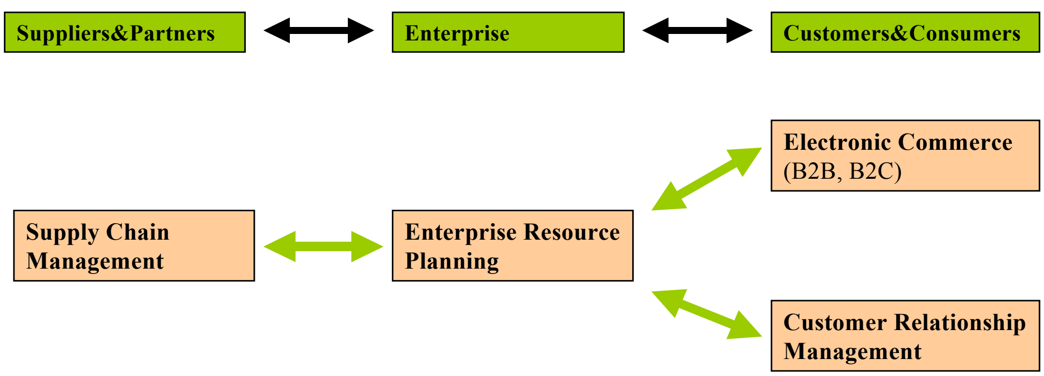

Figure 1: Electronic Business Process and E-business Applications

However it should be noted that IT alone is not a panacea for all SC problems. Even more: the most often quoted problems of online purchasing are not related to technology but rather to logistic and SC problems (Hoek, 2001). This is even truer for traditional companies that are usually even less prepared for new e-commerce related challenges.

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

Business Renovation Goals

Business renovation projects deal with more than just business process reengineering. Business process reengineering remains a buzzword that brings back memories of head count reductions, budget cuts, facility closures, expensive consulting engagements and endless reorganisations that destroy morale and confuse employees, partners and customers. Besides the business process, business renovation projects should also include new technological options as well as different organizational, economics and social views of organizations (Davenport, 1993; Miller., 1994). The business aspects of renovation projects can be shown in Leavitt's diamond (Figure 2). Leavitt's diamond connects processes, structures, culture, technology and people. If one of the elements changes, then other elements have to be changed in order to preserve the stability of the diamond's structure (Burke, & Peppard, 1995).

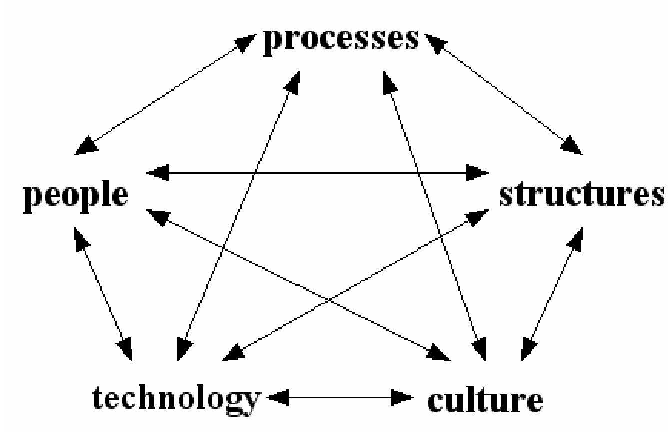

Figure 2:Leavitt's diamond (Burke, Peppard, 1995)

We observe that IT is now taking significant roles in business processes - creating new needs, causing new product development and commanding new procedures. Following full implementation of IT in an organization, these internal changes may also lead to broader shifts in products, markets, and society as a whole (Chang, 2000). The relationship and influence between BPR and IT strategies is a key part of the classic texts in the area (Davenport, 1993; Hammer, & Champy, 1993).

To explore the impact of IT in e-business, we categorize the contributions of IT in two different ways (Chang, 2000). First, it contributes heavily as facilitator to the process of reengineering. On the other hand, IT contributes as enabler to master the new process in the most effective way (Davenport, & Short, 1990).

IT serves as a facilitator through time saving and efficient application such as business modeling and computer aided design tools. Such technology can affect both the product of the design and the process design itself through its analytical, structural, and design capabilities (Chang, 2000). In the first case IT is initiator or driver (not only a facilitator), which is normally seen within those organizations that sell IT as a part of their reengineering solutions (packages...). Business modeling, analysis and simulation, including Computer-aided System Engineering (CASE) tools, are good examples of forms of IT used in the process designing.

IT plays a crucial role as enabler in business process renovation. It should be pointed out that the higher level of procedures' automation brings more or less negative results. Even if some of the achievements of such actions are positive, they prevent the managers from seeing all the opportunities offered by the informatization of a redesigned business process and an infrastructure role of informatics. First, business processes should be analyzed in order to find out if they are well defined, adequate, and ready for the implementation of new IT. For each basic activity in the business value system the effort of IS is to improve products and production processes. Information systems are developed to support the activities in the value chain: Development and use of IS might be to obtain operational efficiency and cost minimization (Gottschalk, & Solli-Saether, 2001).

Only in that way, an improvement of quality, lower costs, and shorter performance times of renovated business procedures and activities could be expected which would lead to increase in customer satisfaction. At first sight the answer seems very simple. Customer satisfaction would grow if we managed to reduce costs, shorten execution times and increase service quality. But after a closer look it becomes clear that we have three excluding goals. For example, we cannot simultaneously achieve the highest possible service quality and the shortest possible execution times.

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). Some authors relate the high capitalisation of Internet companies to new business process models.

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 producing business process models (Eriksson, & Penker, 2000):

- *A business process model helps us understand the business*: one of the primary goals of business process modelling is to increase 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 processes 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. The process modeling methodology with the usage of process maps is shown in more detail in (Popovic, Indihar Stemberger, & Jaklic, in press). In the next section a detailed case study of petrol company is presented.

Case Study

The purpose of this case study is to underline the theoretical findings seen in previous sections; therefore, it is not a detailed description of the petrol company's procurement process. A broader description of the case study can be found in (Groznik, & Mujkic, 2005), whereas, here the most relevant aspects of the case are used here to explain the theoretical concepts mentioned above.

The case deals with the fulfilment/procurement process in an SC that contains the petrol company (with multiple fuel stations at different locations) and the supplier that transports the fuel to the fuel stations from a few larger warehouses. 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 fuel in Slovenia are regulated, the main quality indicator is the number of stock-outs.

The main cost drivers are therefore: number of stock-outs, stock level at the fuel station and process execution costs (work, transport etc.). Lead-time is defined as the time between the start (measurement of the stock level) and the end (either the arrival of fuel 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 that collects information from all fuel stations. It predicts future demand, while taking seasonal and cyclical movements into account. An additional consultation with a fuel station manager is possible, if needed. The needs of several fuel 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, fuel delivered and punctuality of deliveries.

While the description focuses on one typical fuel 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.

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. The main findings of the next sections are however relevant to most SCs regardless of the industry or exact practical situation.

Business Process Modelling

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 in business renovation. One of their main advantages is that employees can be quickly taught how to develop and validate these models (Chen, 1999). They enable analyses of the costs and time needed for the process (Indihar Stemberger, Jaklic, & Popovic, 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, Indihar Stemberger, Jaklic, Kovacic, 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 3. Full sized models and activities descriptions are available from the authors. The developed model was validated by the employees in both companies.

The developed business model helps to understand the current problems and also makes them more visible to all decision-makers in both companies.

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; also the process is 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. the stock levels at all petrol stations);
- each member in the chain is trying to attain its local optimum instead of the global chain's optimization; and
- consequently both the stock levels and transportation costs are higher than necessary.

Business modelling plays the role of a facilitator of changes. It helps identify some of the above mentioned problems. In connection with business process simulations it also helps 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, Tang, & Bennet, 2004; Burgess, 1998; Kidd, Richter, & Li, 2003).

Business Renovation

Based on the mentioned problems, several improvements were 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 4.

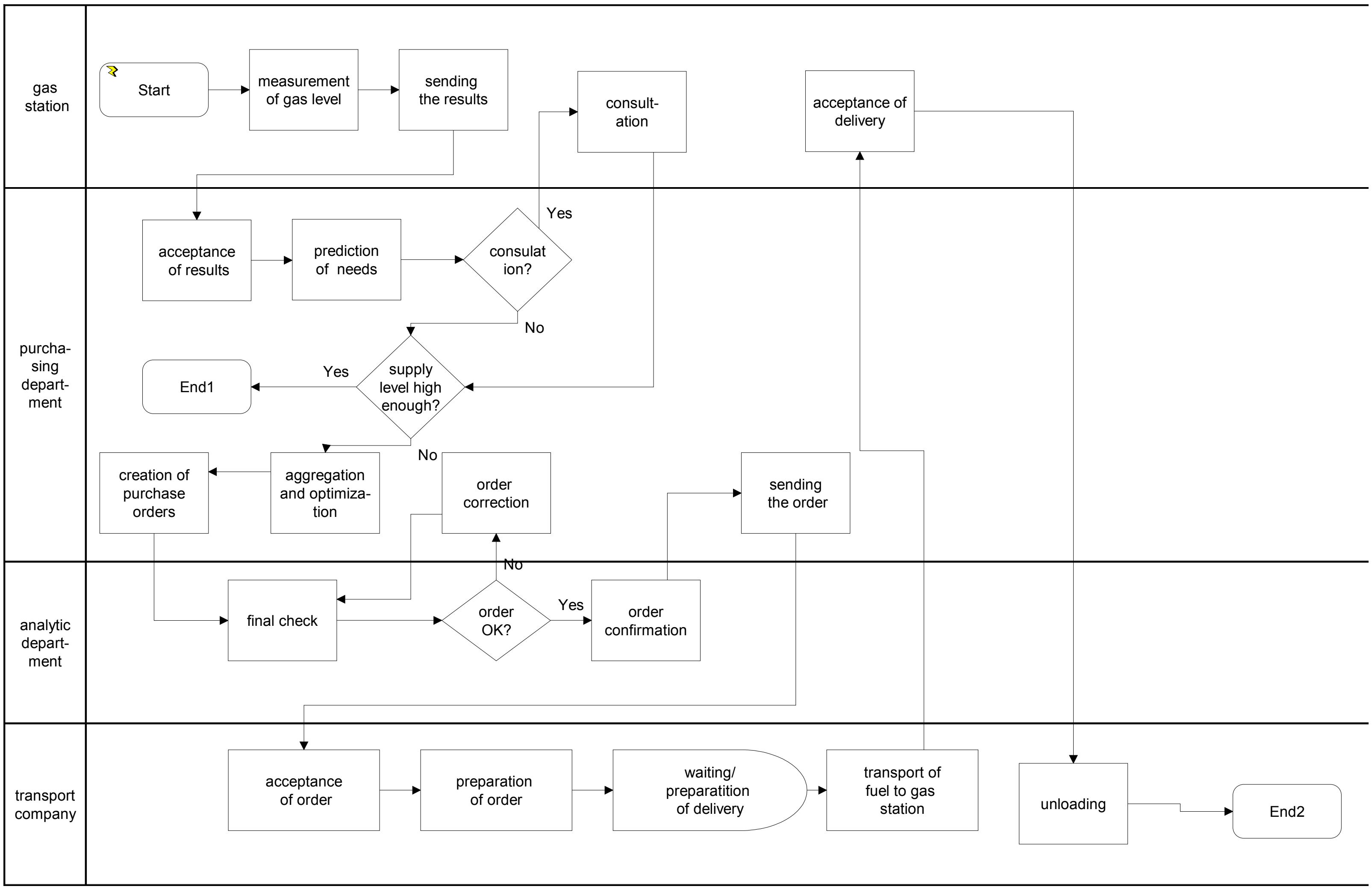

Figure 3: AS-IS model

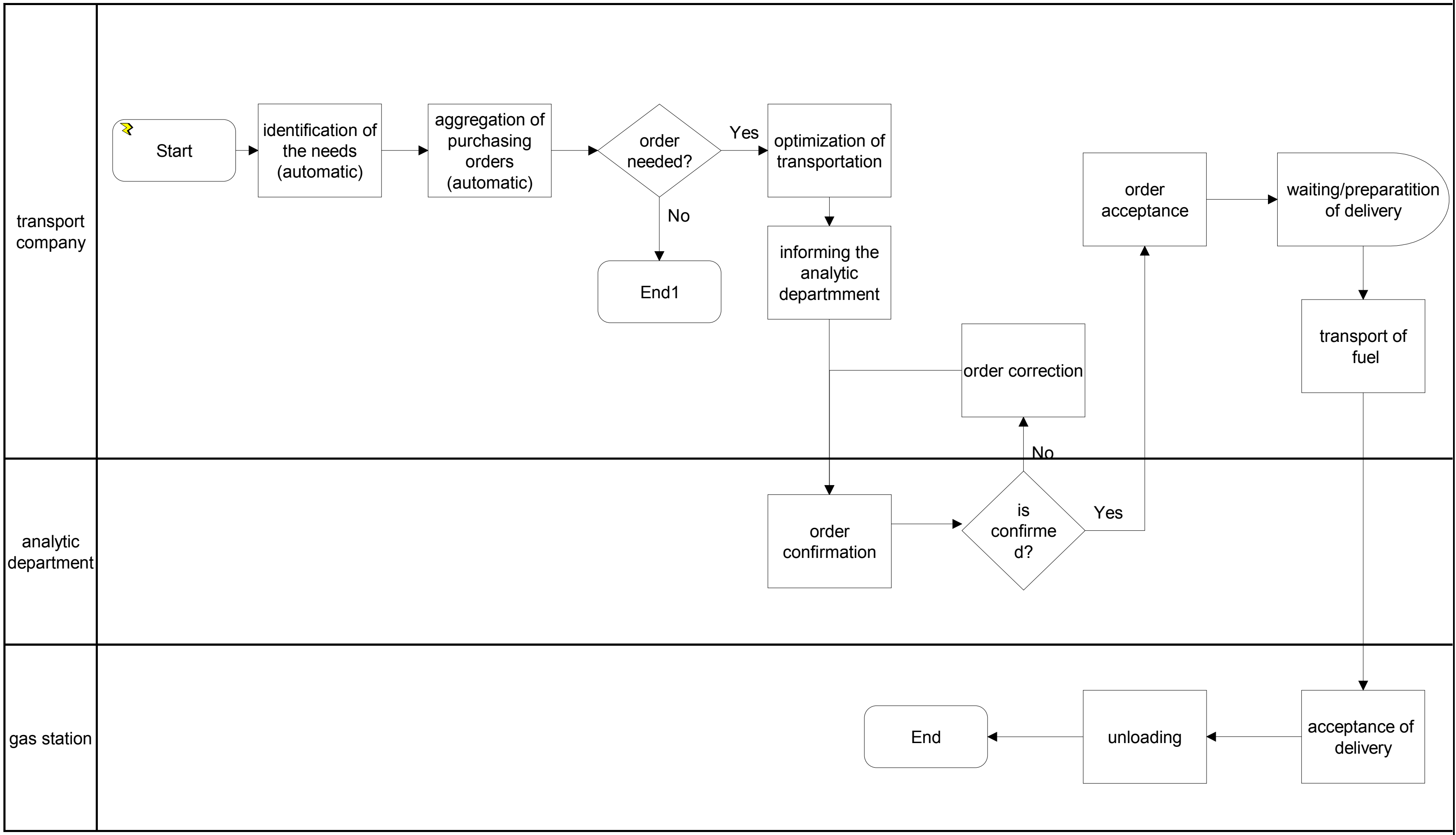

Figure 4: TO-BE model

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 with material requirements planning, data mining, operations research and everything can be gathered 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 proposed changes are:

- the measurement of petrol is now fully automatically; the stock level information is exact;
- the stock levels from all fuel stations are instantly available to the transport company;
- 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, & Tatsiopoulos (2004) for a detailed description of such a system); and
- in the long-term the locations of the warehouses can also be optimised to bring further reduction in costs and transportation times.

Further advantages not directly visible from the figures include:

- due to the use of optimisation methods with full information 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 previously.

The role of the 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 beneficial to do so for a renewed model.

Petrol Supply Chain and Transfer of Information

Special attention in renovation efforts is paid to changes in transfer of information. IT would enable an efficient and cheap transfer even in the AS-IS model as the use of e-mail or 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, & 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 twofold:

- 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; and
- 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 earlier only local optimisation at 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. This is our answer to the previously mentioned different views on the benefits of information sharing.

Measuring the Business Renovation Effects

The effect of the changes can be estimated with a simulation of business processes (the methodology, advantages and some problems of this approach are presented in depth in (Bosilj-Vuksic et al., 2000) and simulations of supply and demand. The results of the simulations enable the measuring of the effects of possible experiments in business process models (Eriksson & Penker, 2000).

With the first simulation we estimated changes in process execution costs, lead-times and employee workloads. The methodology used (Bosilj-Vuksic et al., 2000) 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 and 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 weighted up against the costs needed to make those changes to find out the business feasibility of such changes (as shown in Groznik, & 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 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, fuel station manager, fuel 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 fuel 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 1. The label ‘Yes’ refers to those transactions that led to the order and delivery of fuel, while the label ‘No’ means a transaction when an order was not made since the fuel level was sufficient.

Table 1: Comparison of simulation results for the AS-IS and TO-BE models

transaction	no.	av. lead-time (in hrs)	av. work (in hrs)	av. wait (in hrs)	av. costs
Yes (AS-IS)	22	28.53	14.06	13.61	$1,054.43
No (AS-IS)	67	5.39	4.6	0.00	$81.72
Yes (TO-BE)	22	10.82	5.87	4.94	$320.17
No (TO-BE)	1058	<0.01	<0.01	0.00	$0.09

The average process costs are reduced by almost 70%, while the average lead-time is cut by 62%. 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 with these business process simulations

Another interesting observation is that even every NO transaction in the AS-IS model costs $82 for every fuel 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 a single company is unlikely to become involved in such a renovation project unless it can expect benefits for itself. The results in Table 2 show that both companies can realise important savings – the results can be used to convince the managers of each company 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.

Table 2: Total costs per department (3 months)

department	AS-IS	TO-BE	index TO-BE (AS IS =100)
analytic department	$51.45	$72.39	141
fuel station	$865.64	$167.53	19
purchasing department	$8,069.69	$0.00	0
fuel company total	*$8,986.79*	*$239.92*	*3*
transport company	*$19,686.42*	*$6,903.31*	*35*

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 the use 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 supply and demand of fuel. A three-month simulation of level of stock at a fuel 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 first simulation), demand prediction for various times of the day (using the old method and the new neural networks based method) etc. The reorder point is set at the average demand for fuel in lead-time plus a certain safety stock. Each order consists of 30.000 litres of fuel. All inputs (e.g. costs for holding a unit of inventory; costs of stock-outs; mistakes in the measurement of fuel in the AS-IS model) are based on real industry data.

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.

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. The typical stock fluctuations for one run of simulation (with multiple realizations) are shown in Figure 5.

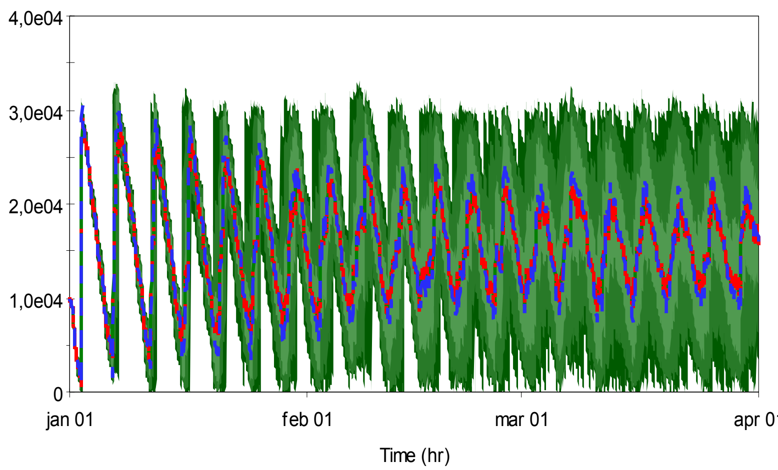

Figure 5: Stock fluctations in multiple simulation realizations

Three different situations were studied:

- current situation in the AS-IS model (blue line in figure 6);
- the TO-BE model with the same number of orders (red line in figure 6); and
- the TO-BE model with twice the number of current orders (yellow line in figure 6).

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. In Figure 6 the relation between reorder point and inventory costs is shown. The reorder point is the perceived level of fuel when the order is placed (in the TO-BE model this is the same as the actual level, while in the AS-IS model a 5% variation is possible due to an inaccurate measurement method). Inventory costs are the sum of inventory holding costs and the costs and loss of profit for each stock-out.

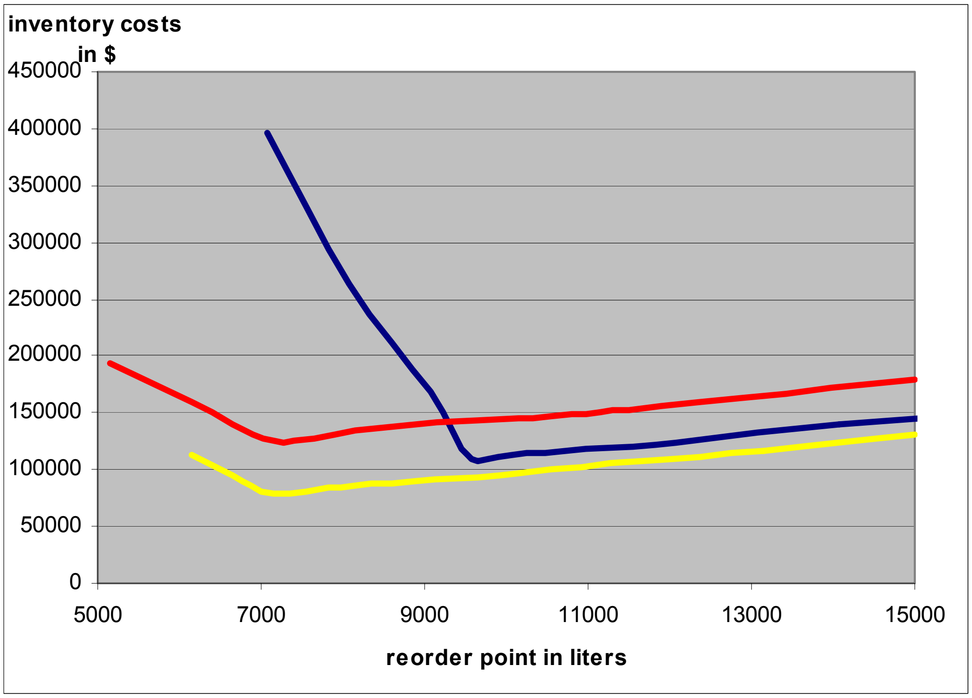

Figure 6: Relation between costs and reorder point in different models

The first situation is shown with a blue line, the second in red, and the third in yellow.

The recommended reorder point is visible for all three situations. The reorder point is much lower in both renewed models. However, it is obvious that while the cost-curve has shifted to the left in the TO-BE model, put simply the reduction in process lead-times and costs do not lead to changes in the minimum of that curve. However, since the costs of one order are reduced by 70%, it is possible to double the number of orders and still reduce the previous total order costs by 40%.

Therefore, for our case business renovation brings considerable reductions in process execution costs, lead times and workloads of employees. It does not reduce inventory holding costs. However, the reduction of process costs can enable the increase in order frequency and consequently inventory related costs.

The results of both simulations substantiate 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.

While the above findings may not hold in each individual case, the presented methodology enables the repeat of a similar experiment to estimate possible changes for that case.

Potential Implementation Problems

While the main advantages of the proposed changes are clear, certain general problems were identified. Apart from the possible technological problems, that should not be neglected, the following issues were identified:

- 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 e. g. 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 a problematic issue 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, & Cavalieri, 2004). Indeed, the lack of trust between business partners is one of the main hindrances to collaboration in the SC context (Barrat, 2004; Ireland, & Bruce, 2000).
- Asymmetric distribution of costs and benefits: since substantial investments are needed from both sides, but the transporter realises less benefits, while taking on new responsibilities, risks 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 that was based on the number and punctuality of deliveries to a system based on the quality of services for the final customer and average inventory costs for the petrol company.
- Different organizational cultures and leadership styles: these will have to be aligned in to suit the SC. Although changes in organizational culture were not examined in this case study, its importance has to be emphasized.
- A new way of thinking: since employees will have to seek solutions on the SC-levels – global instead of local optima and learn to cooperate closer with its supplier/buyer. Changes in human behavior are usually the hardest to achieve.

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-phased approach to estimating the different benefits of business process renovation with the use of simulations. The transfer of information brings important advantages in process costs and lead-times, while the resulting possibility of smaller and more frequent orders means reduced inventory costs.

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